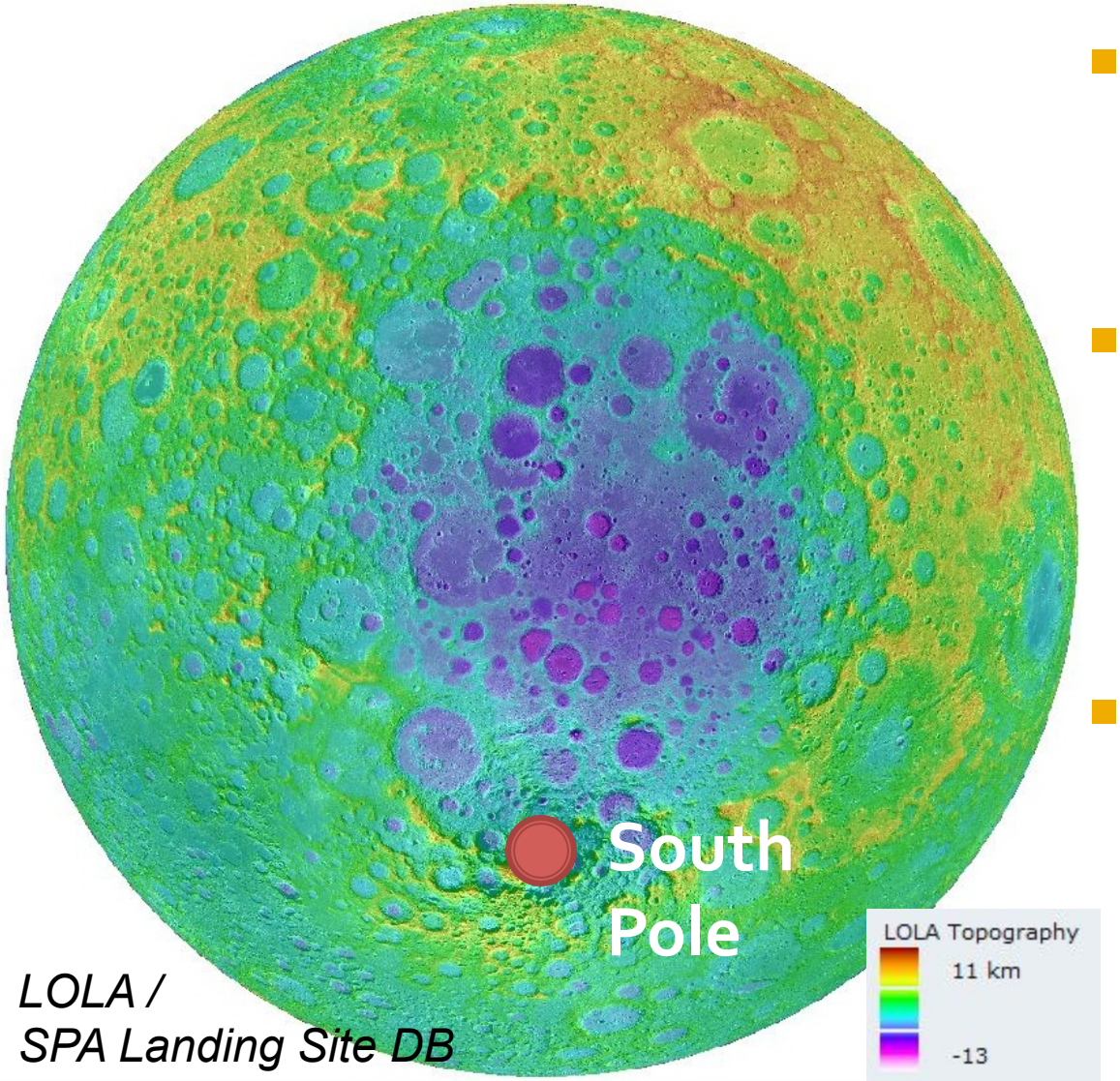
The Diverse Local and Regional Stratigraphy of the South Pole – Aitken Basin

Daniel Moriarty
Carle Pieters

SSERVI ESF
July 22, 2014

South Pole – Aitken Basin (SPA)



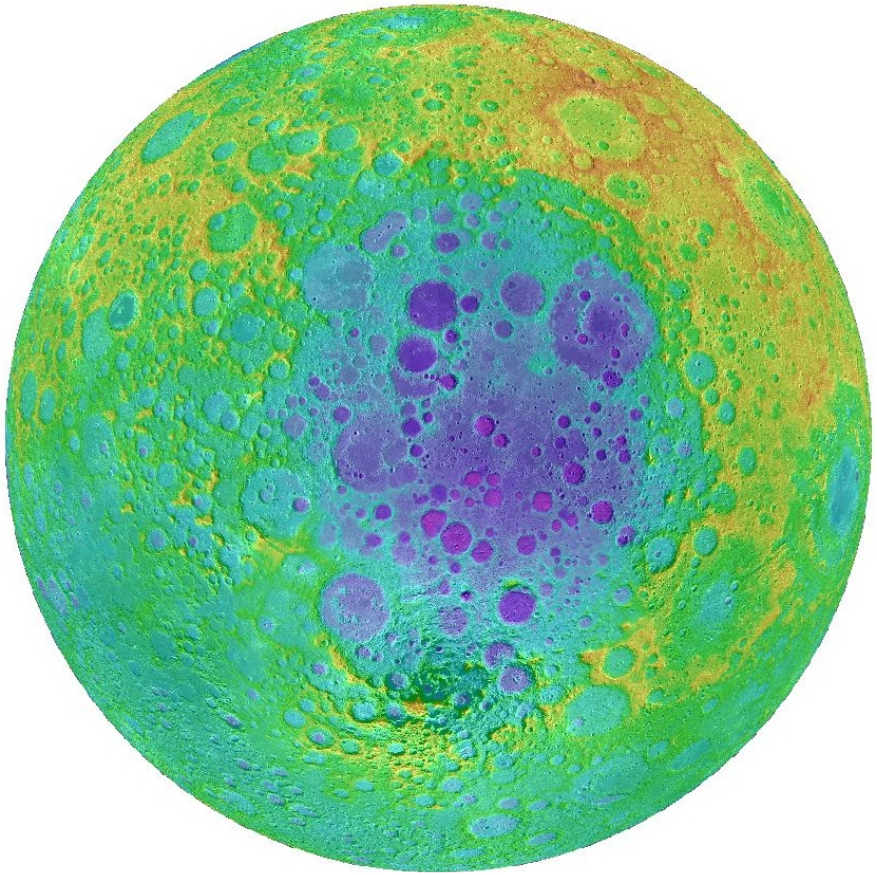
LOLA /
SPA Landing Site DB

- SPA is the largest, oldest preserved basin on the Moon.
- The impact event may have melted or excavated mantle materials.
- The SPA interior exhibits pervasive mafic materials and significant diversity.

Long-Term Goals

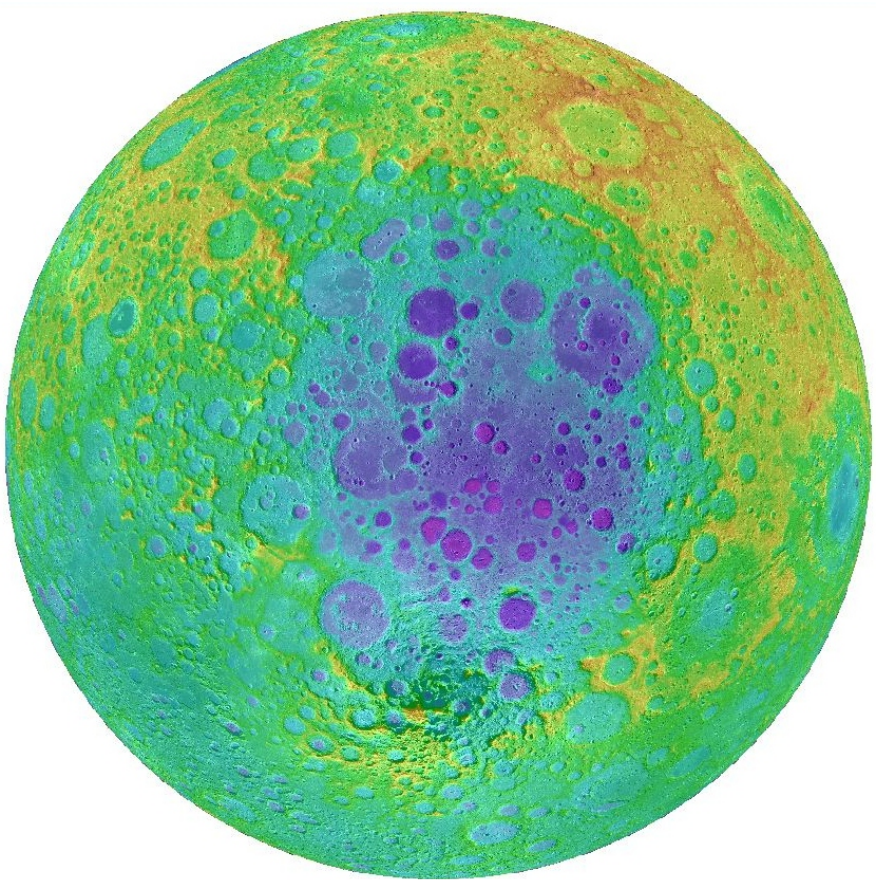
Characterize the compositional diversity of SPA materials in order to constrain:

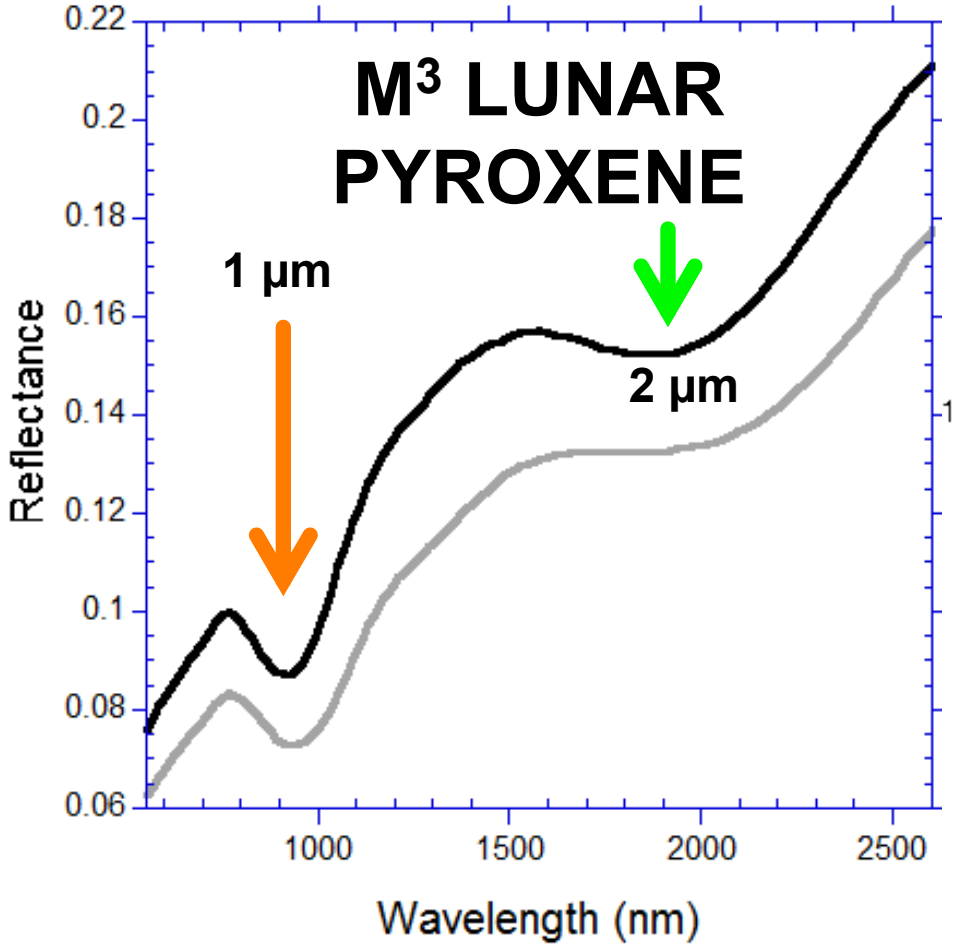
- SPA formation and evolution (and large impact processes in general)
- The structure and composition of the lower crust (and possibly upper mantle)

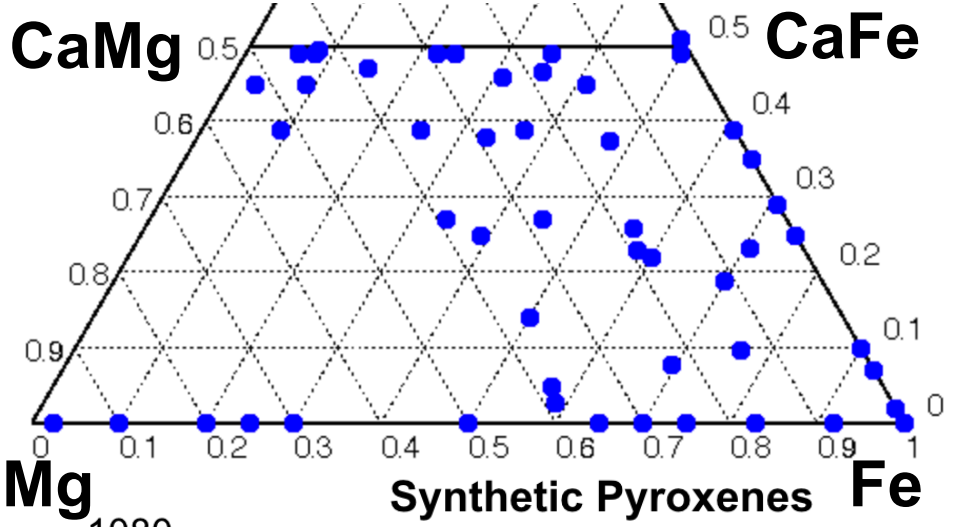


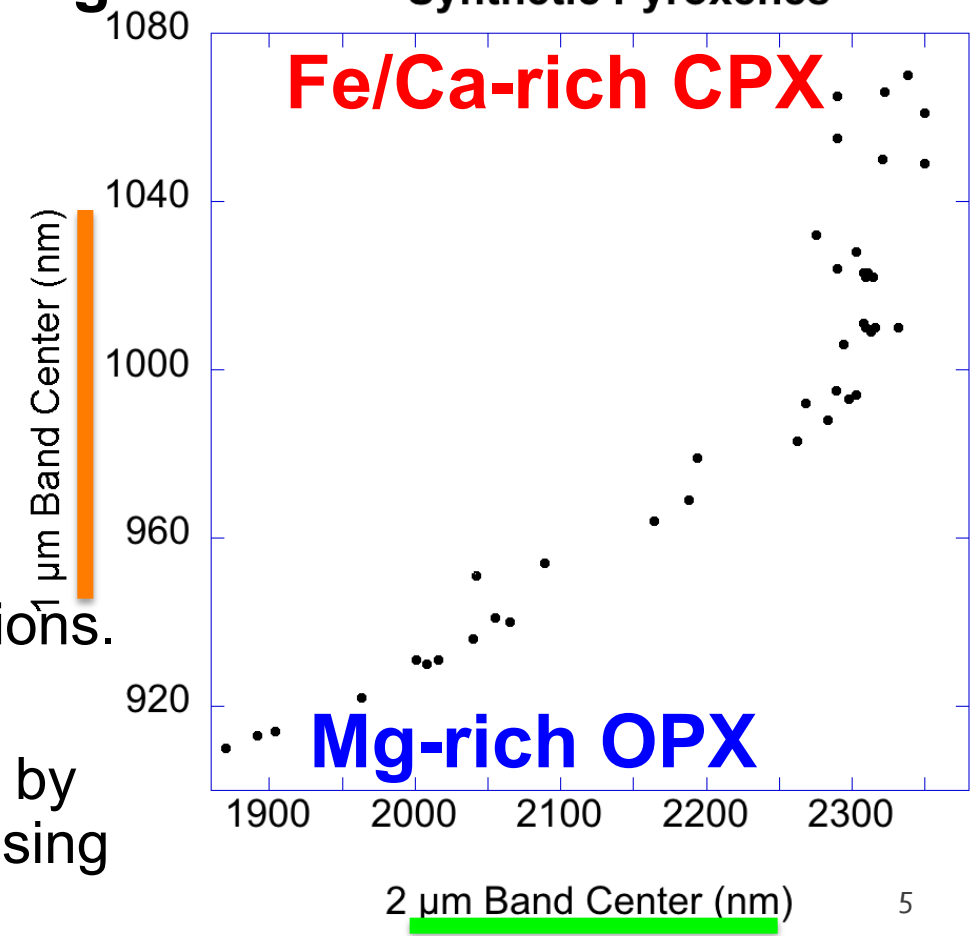
Primary Goal for This Talk

- Constrain the compositional diversity of the SPA subsurface using central peaks
- Investigate the nature of Mafic Mound: an unusual lithology within SPA

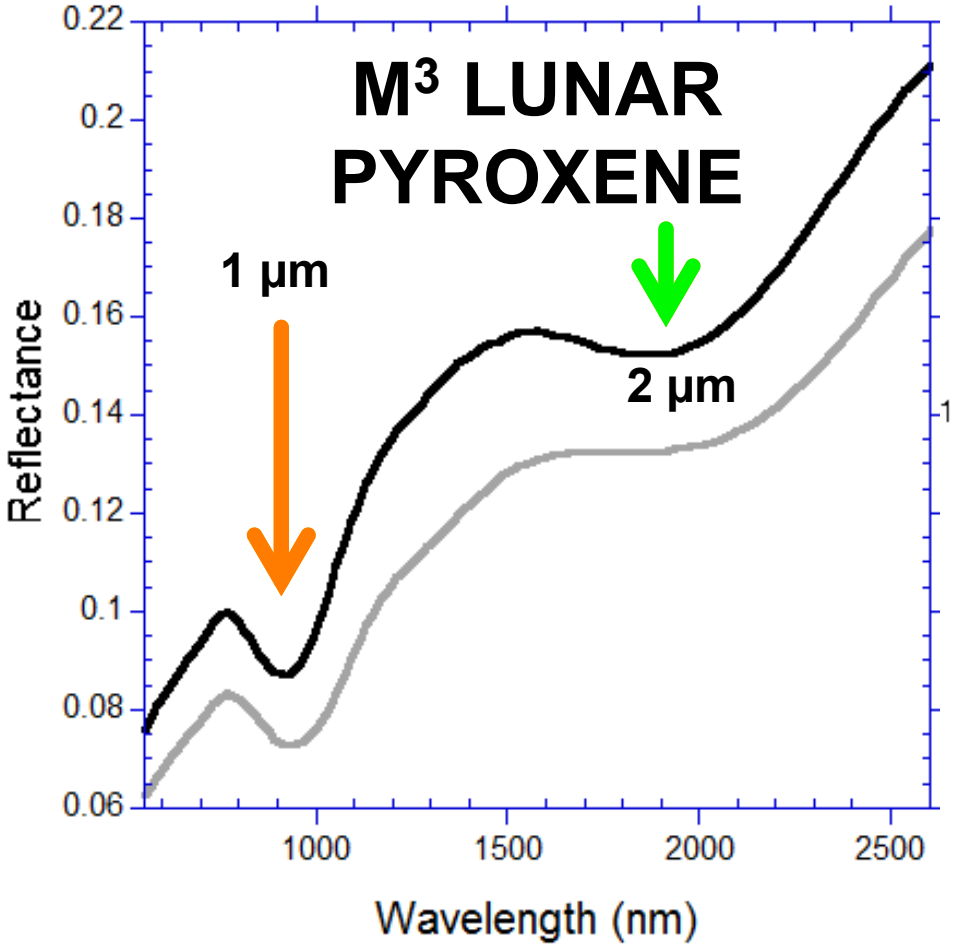


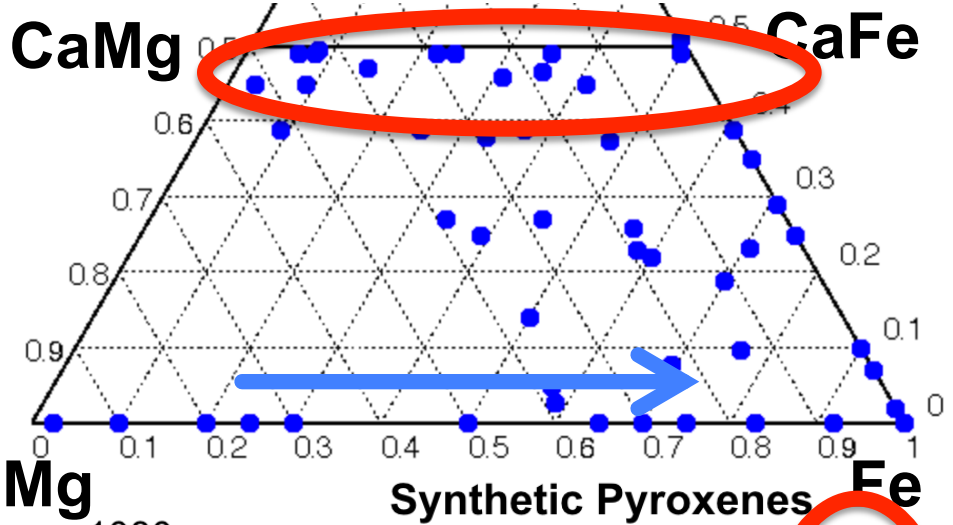


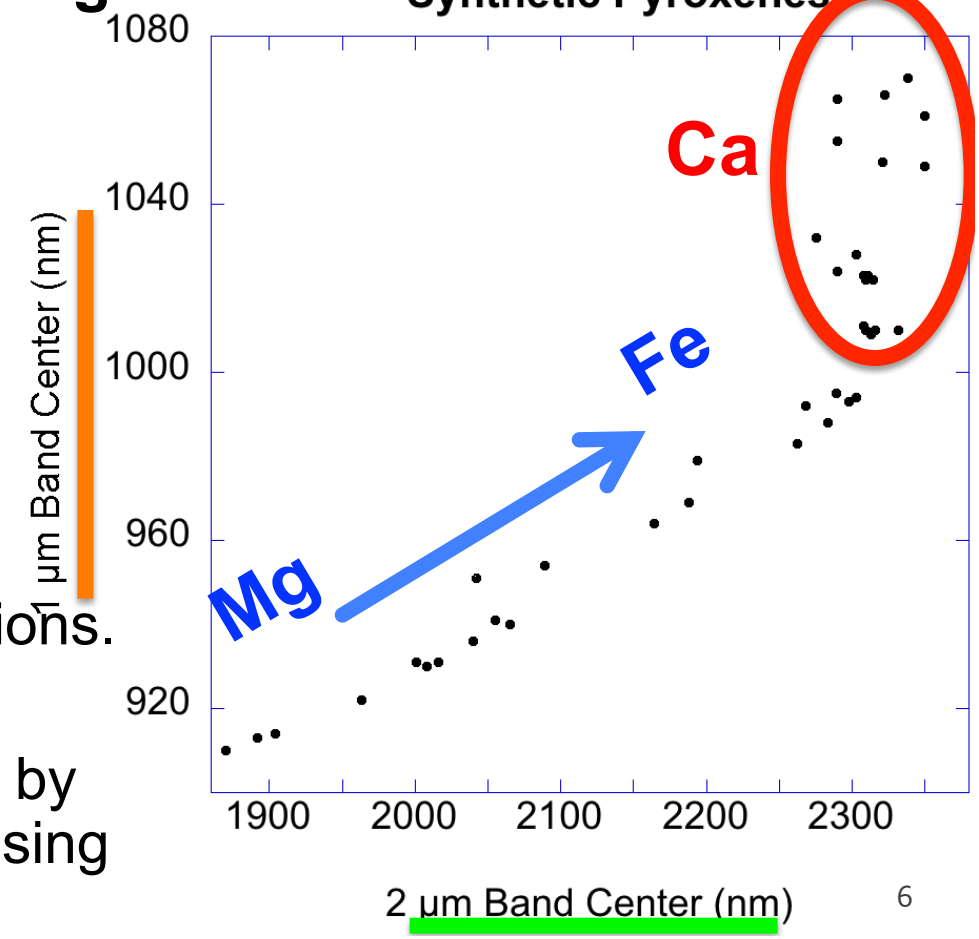




- Pyroxenes exhibit diagnostic absorption bands related to mineralogy and formation conditions.
- The composition/band center relationships were characterized by *Klima et al.* [2007; 2008; 2010] using the Modified Gaussian model.







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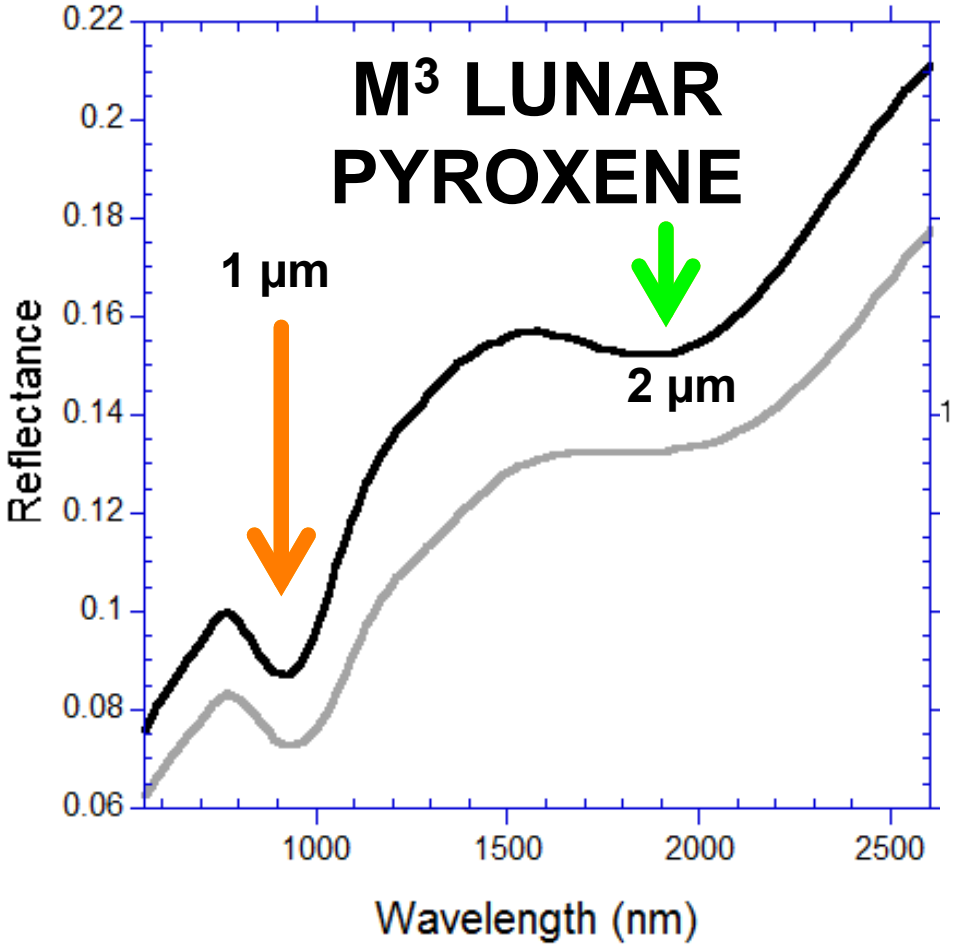

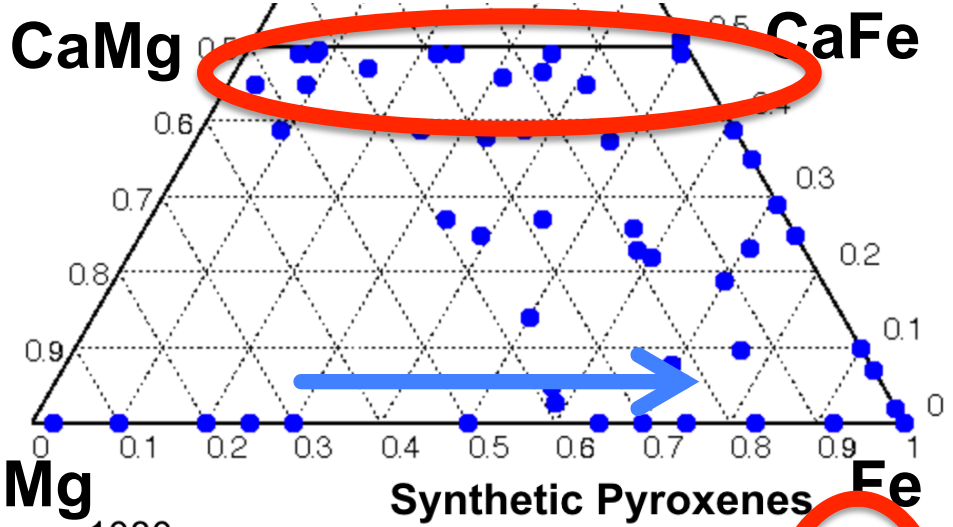

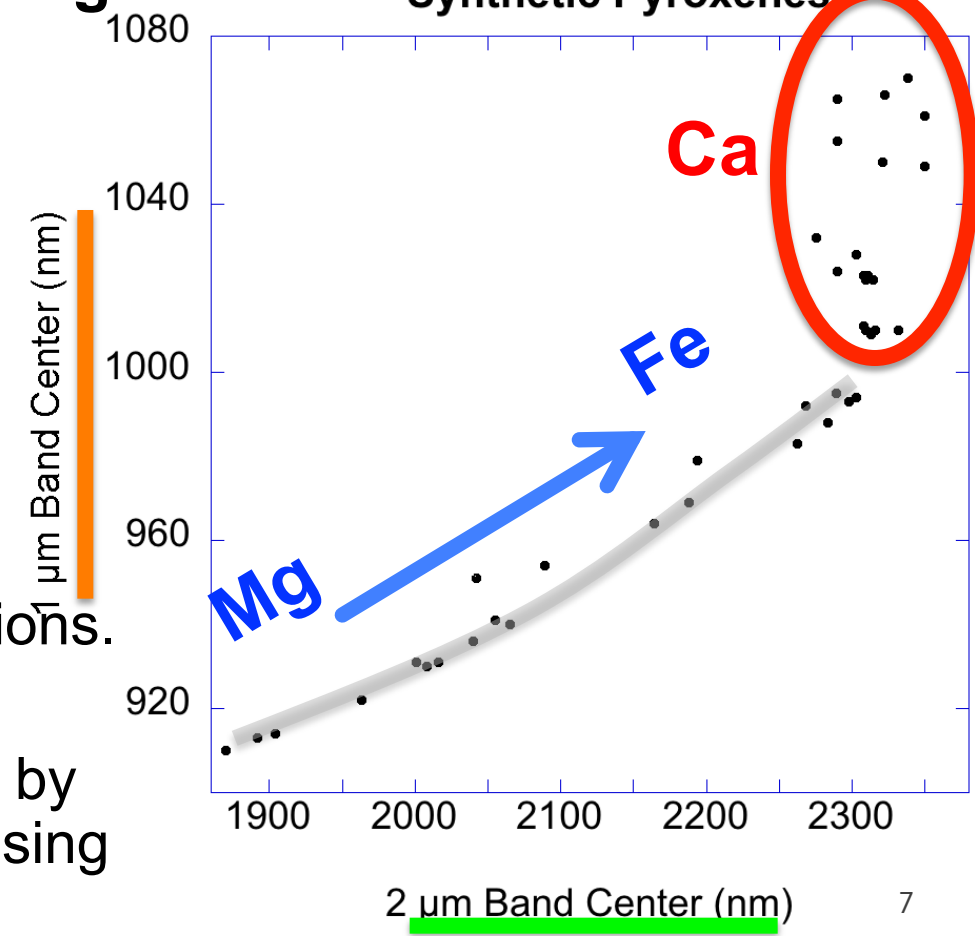

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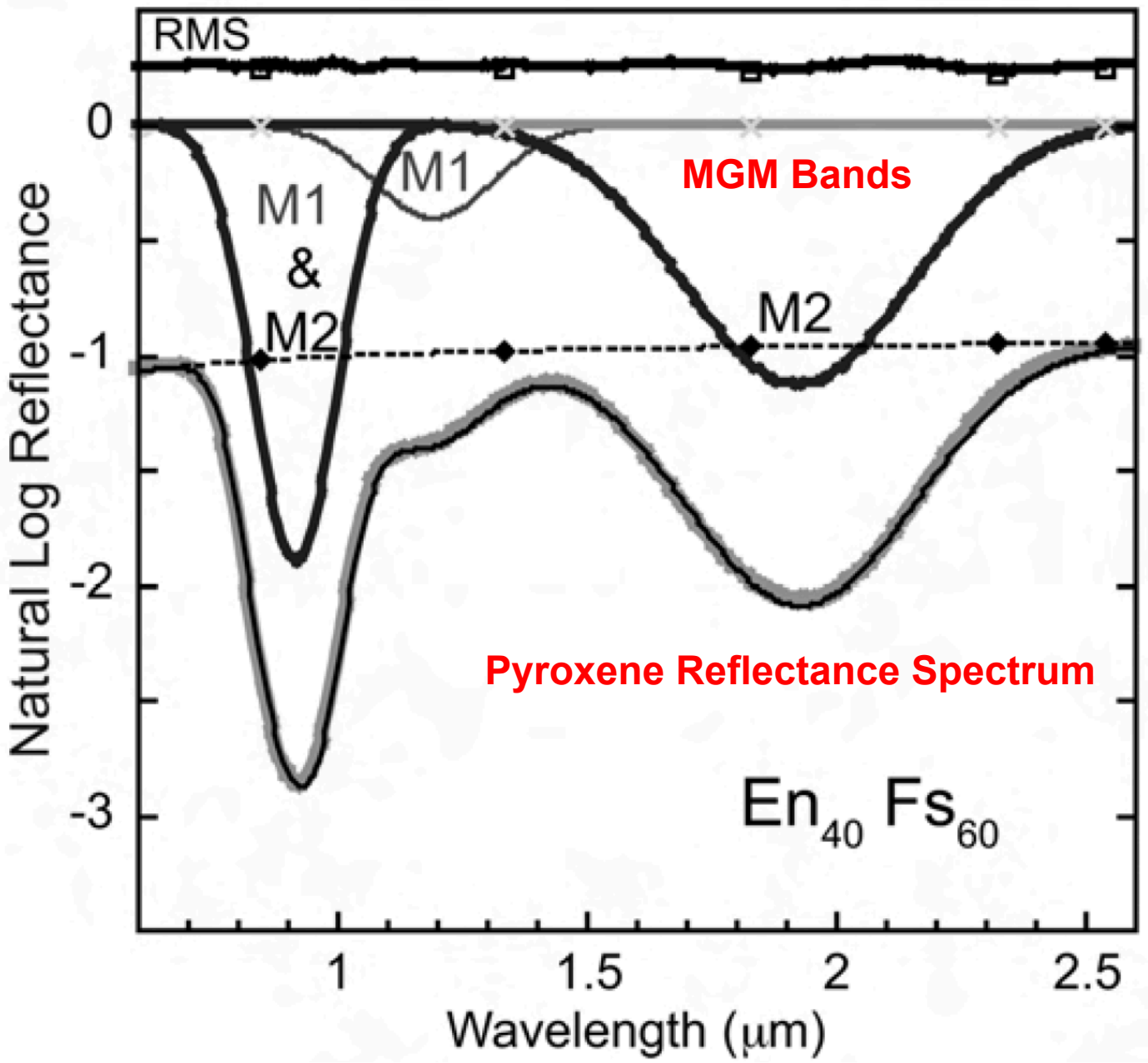
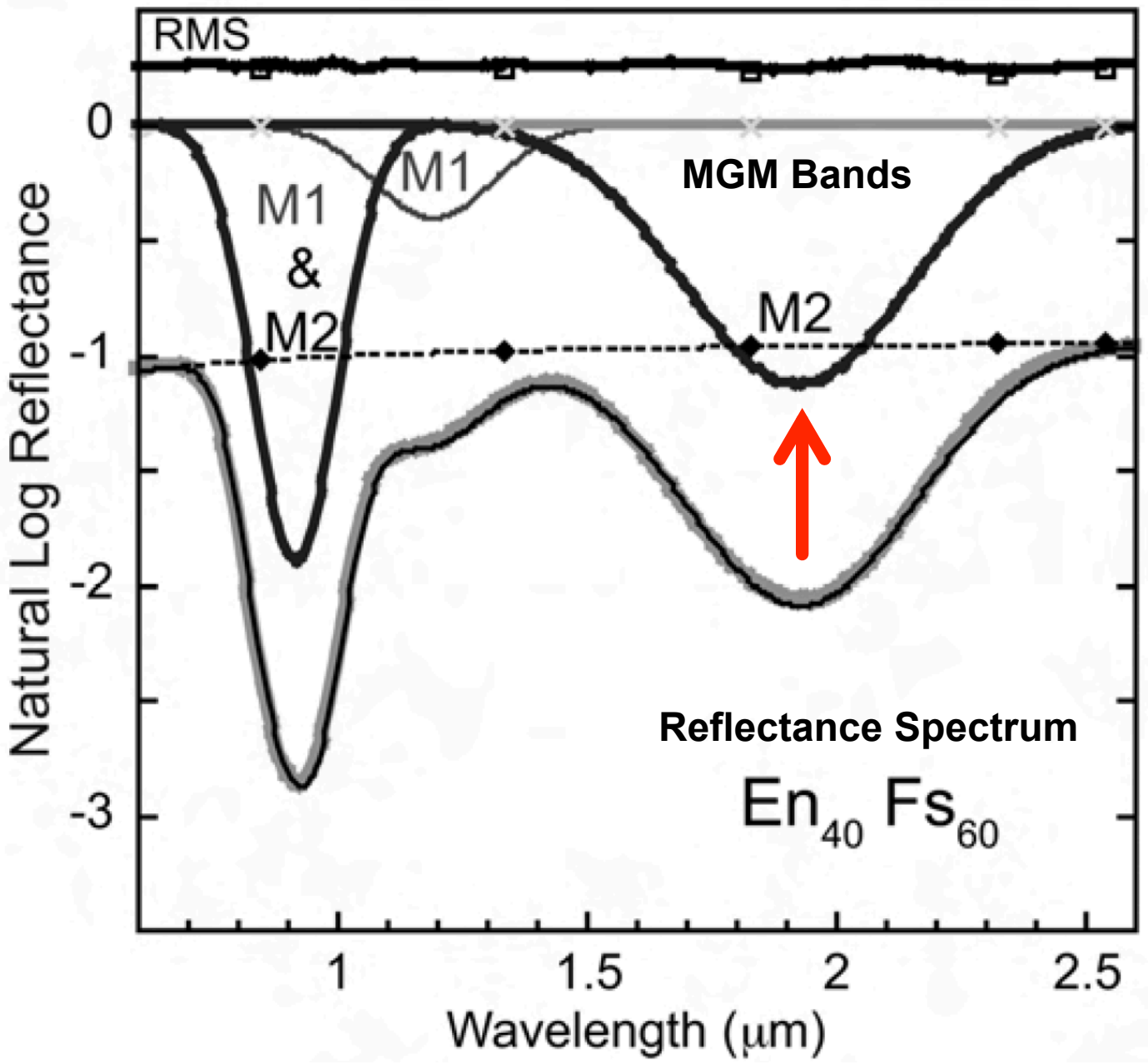


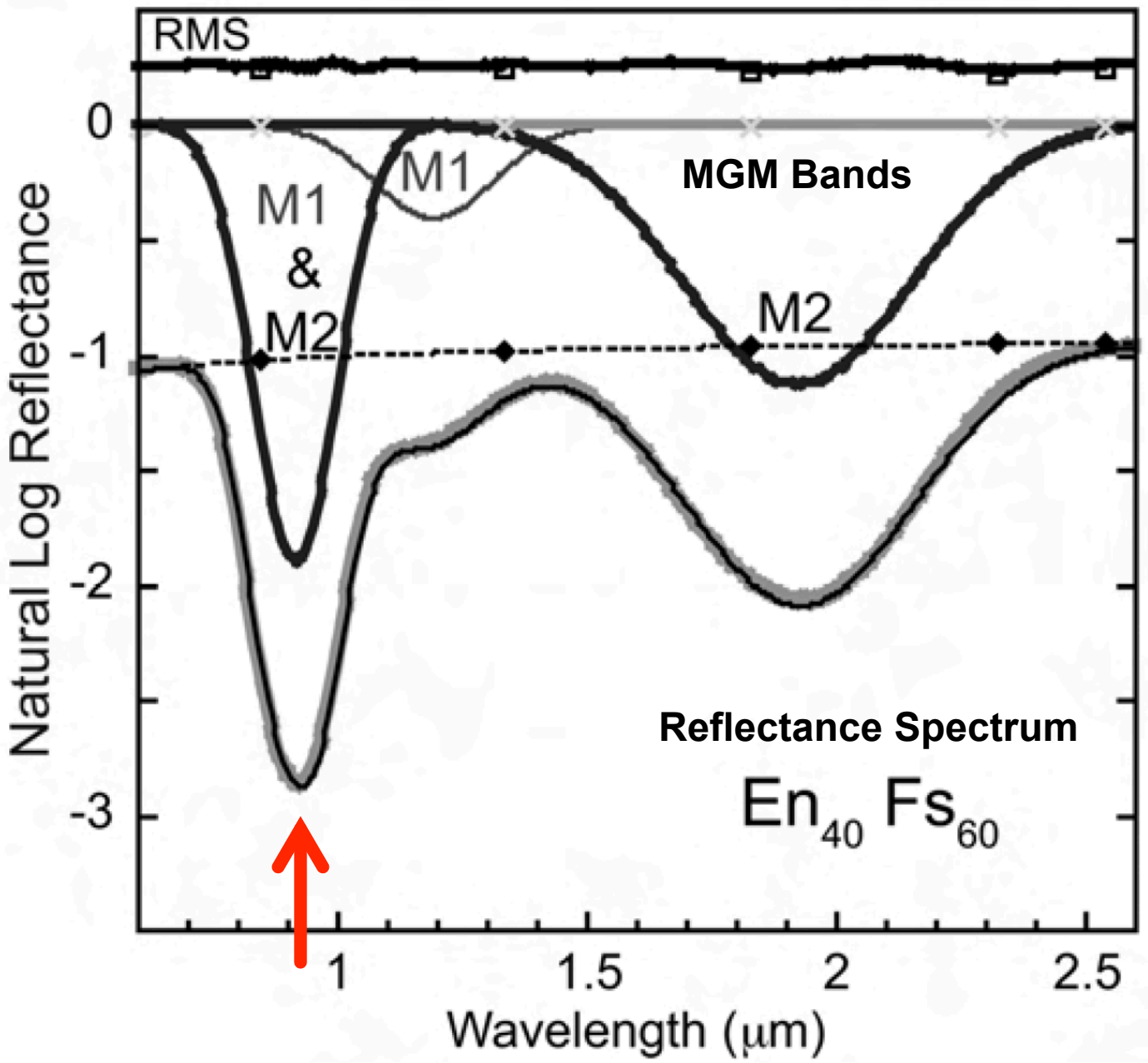
- Pyroxenes have two octahedral cation sites: M1 and M2. (Fe^{2+}, Mg^{2+}, Ca^{2+})
- Absorption bands arise from Fe2+ in these sites.
- The M2 site is larger and more distorted than M1.

Klima et al., 2008



- The 2 μm band arises solely from Fe^{2+} in the M2 site.
- The 1 μm results from Fe^{2+} in the M1 and M2 sites.
- Fe^{2+} in the M1 site also produces a band at 1.2 μm.

Klima et al., 2008



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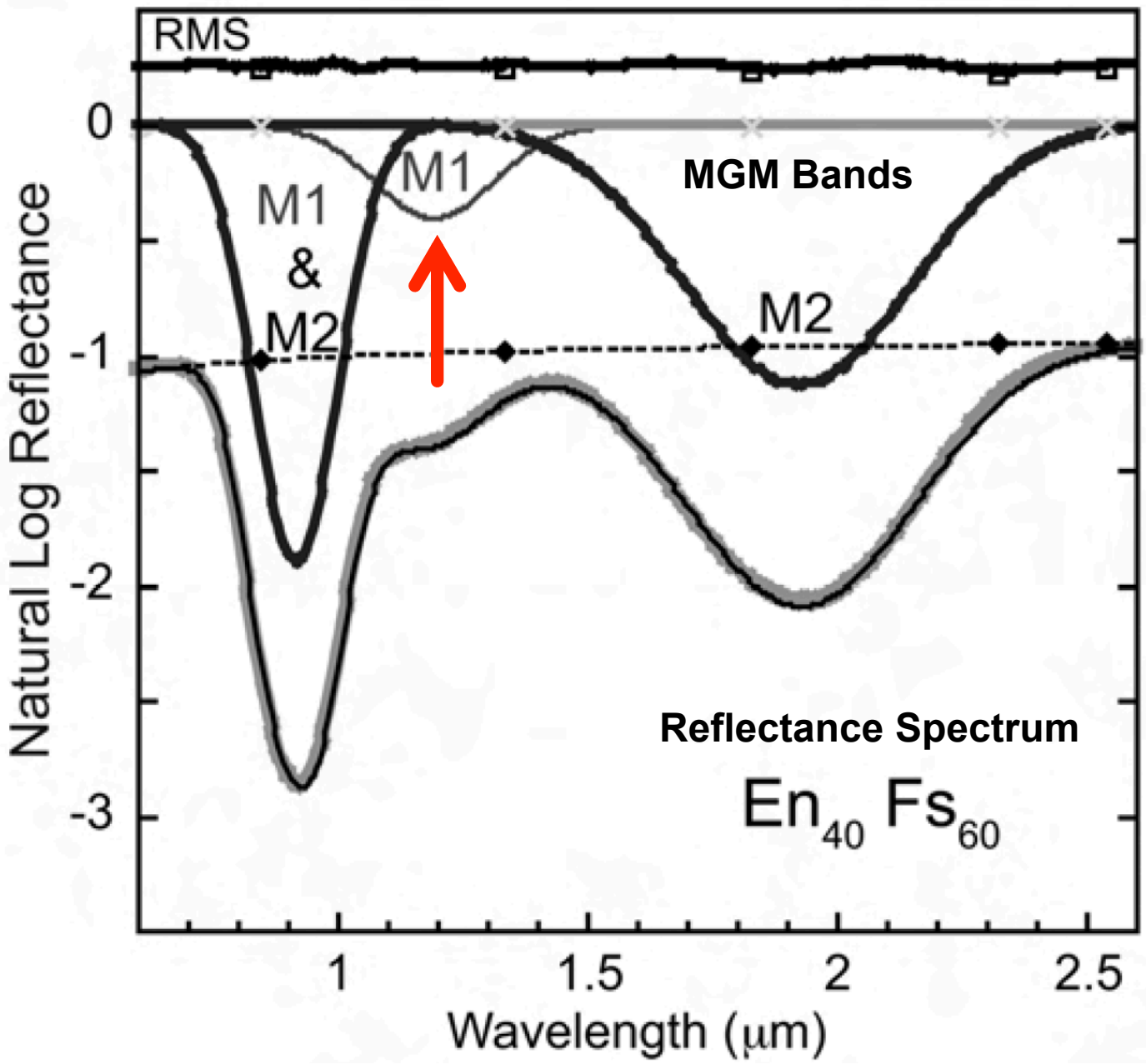

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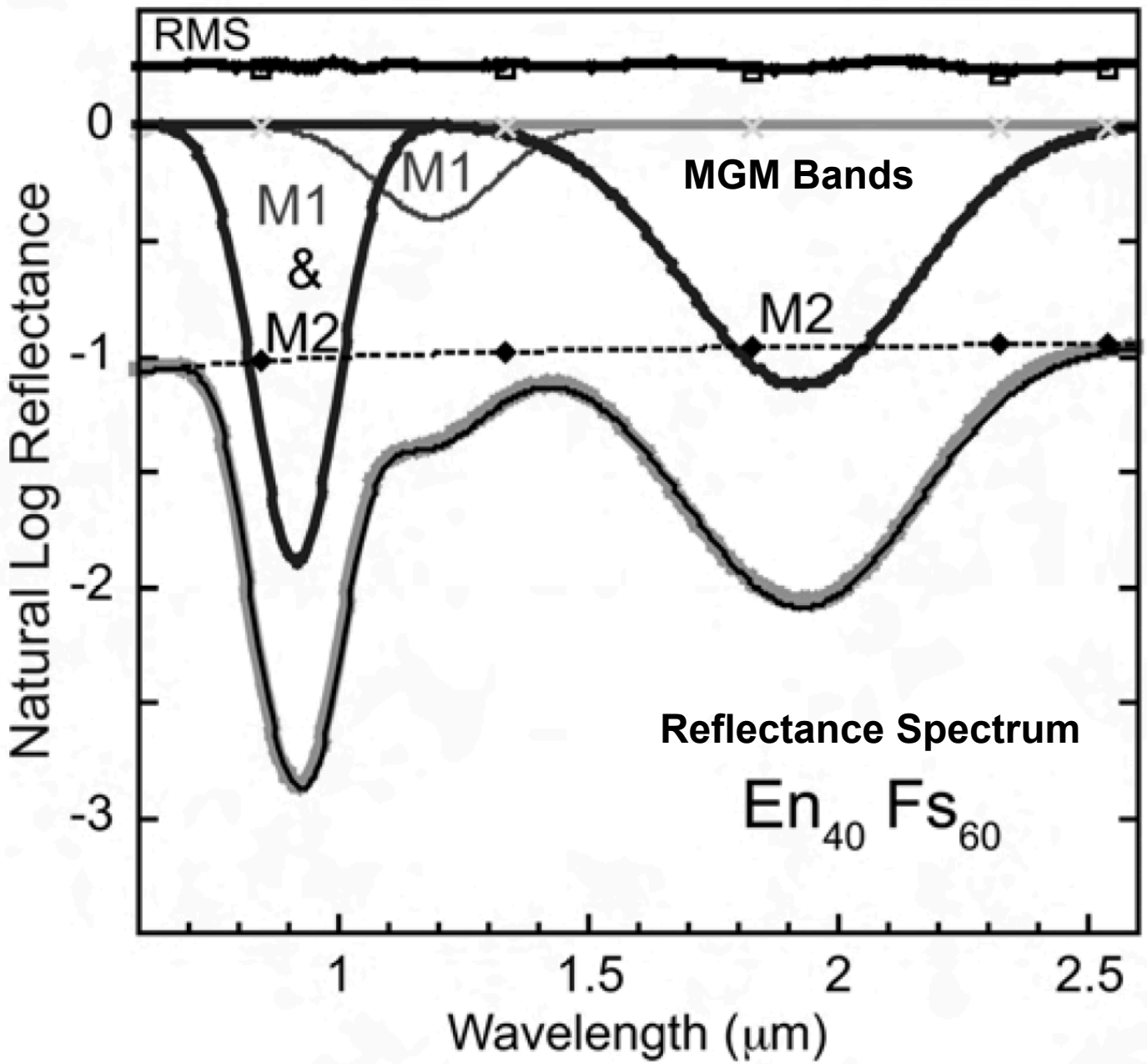
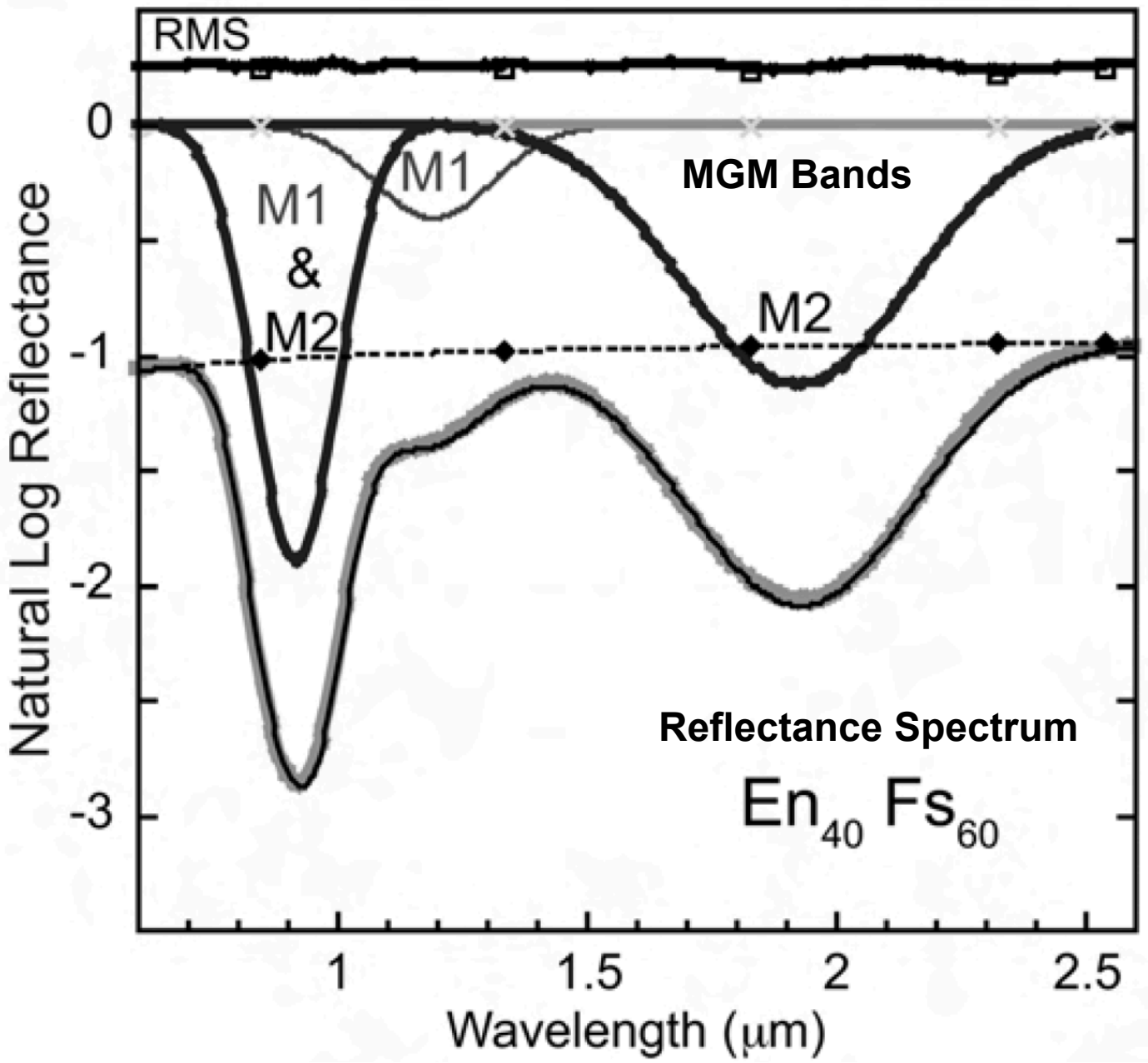


- In Fe-Mg pyroxenes, Fe^{2+} normally prefers the M2 site, as it is slightly larger than Mg^{2+}.
- Ca^{2+} is significantly larger than Fe^{2+} and Mg^{2+} and strongly prefers the M2 site.

Klima et al., 2008

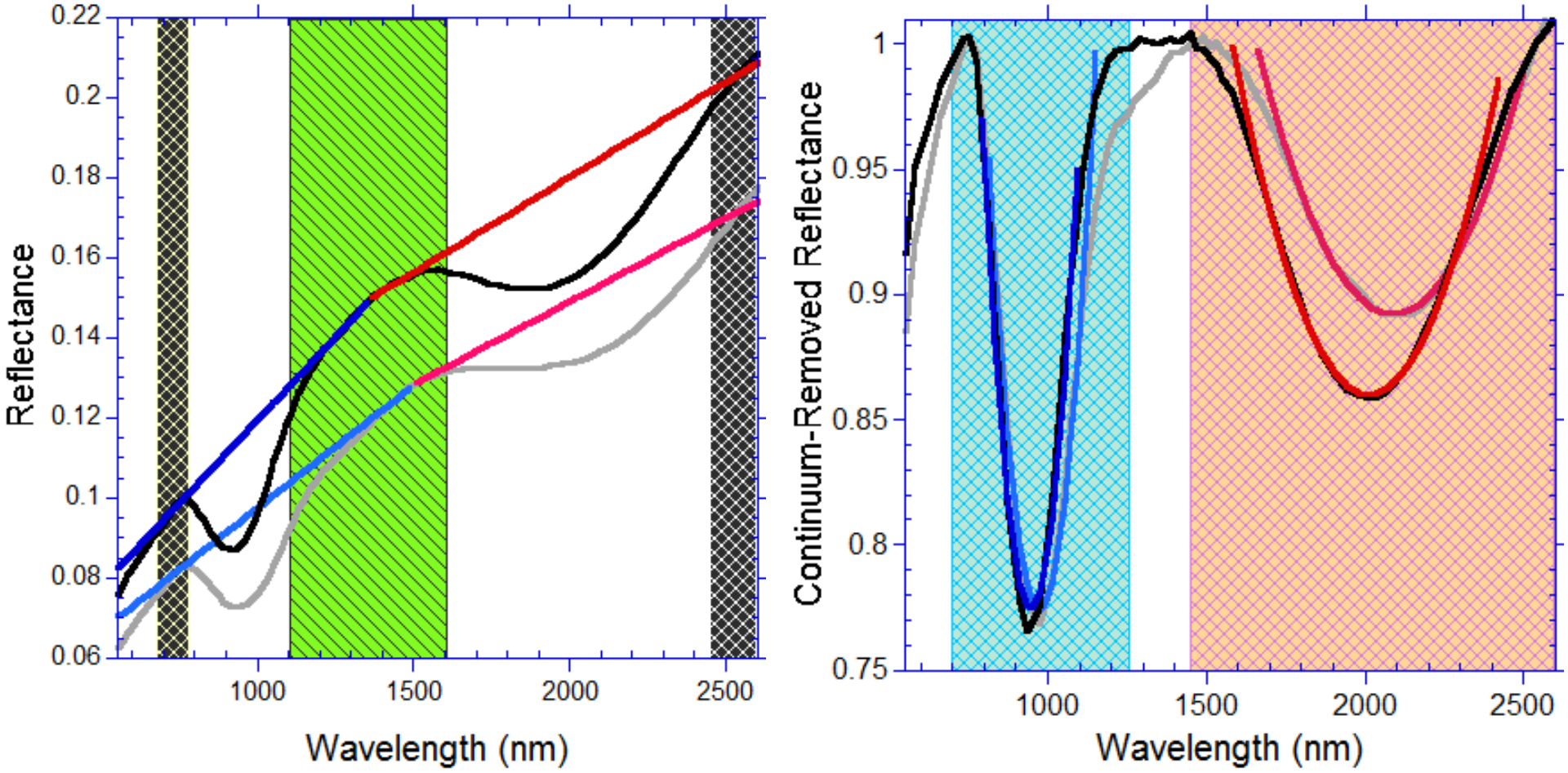


- Very high Ca contents can force Fe^{2+} into the M1 site.
- Rapid cooling can also trap Fe^{2+} into the M1 site.
- For pyroxenes of similar compositions, a stronger 1.2 μm band indicates faster cooling.

Klima et al., 2008

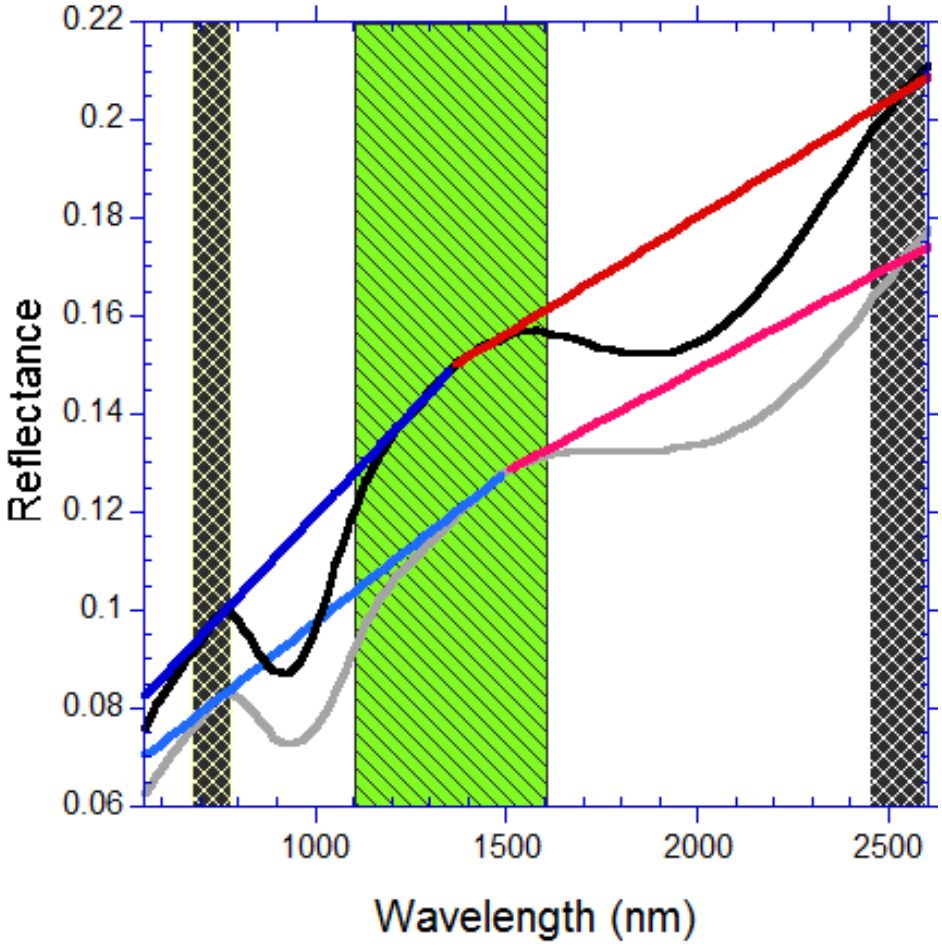
Parabolas and Linear Continuum: The PLC Technique

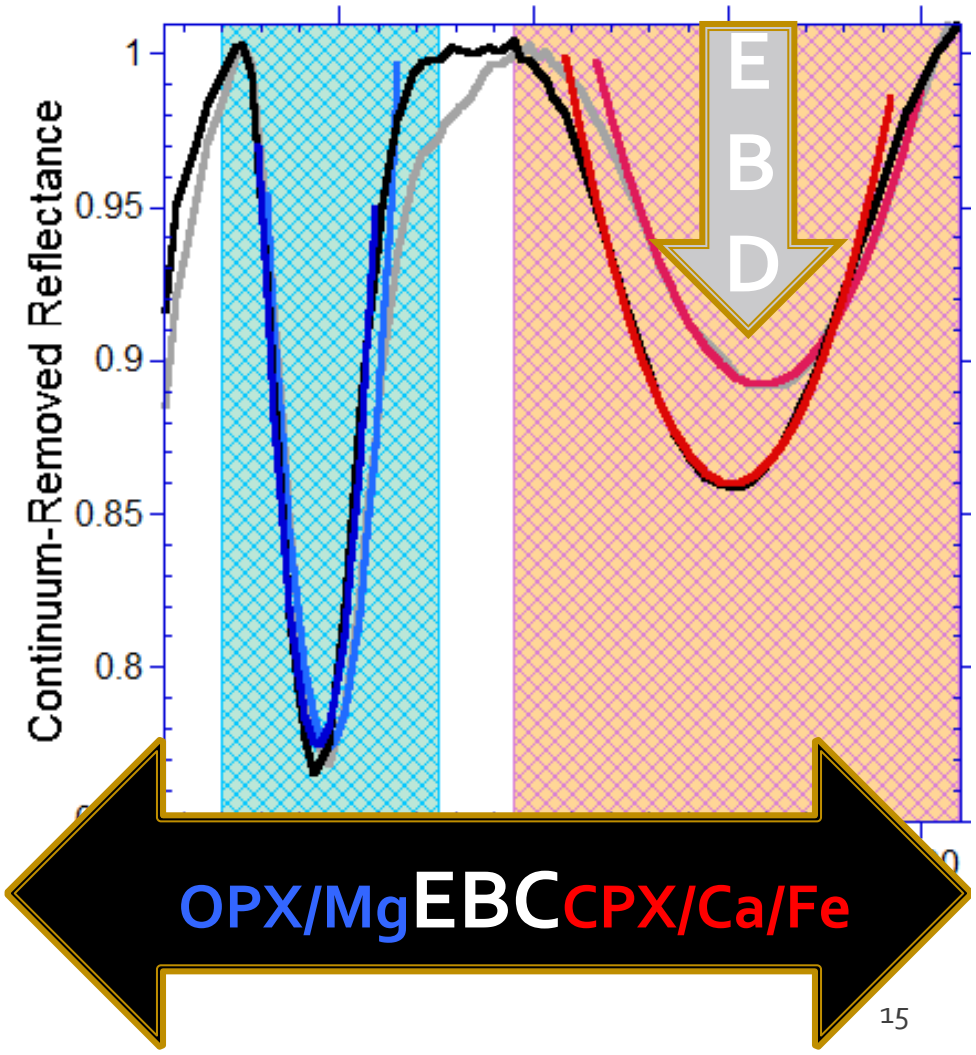
Continuum Fitting and Removal



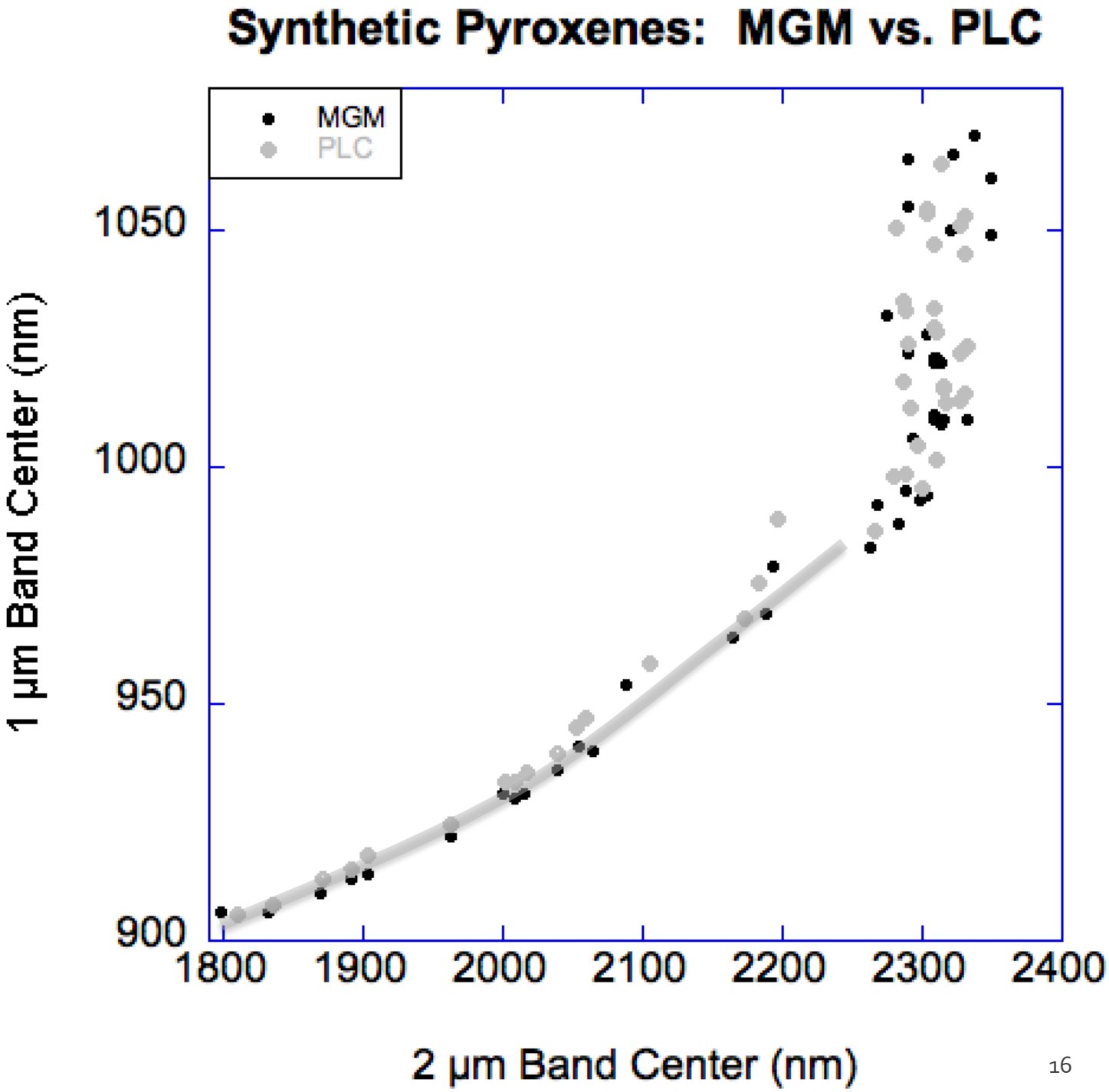
Parabolas and Linear Continuum: The PLC Technique

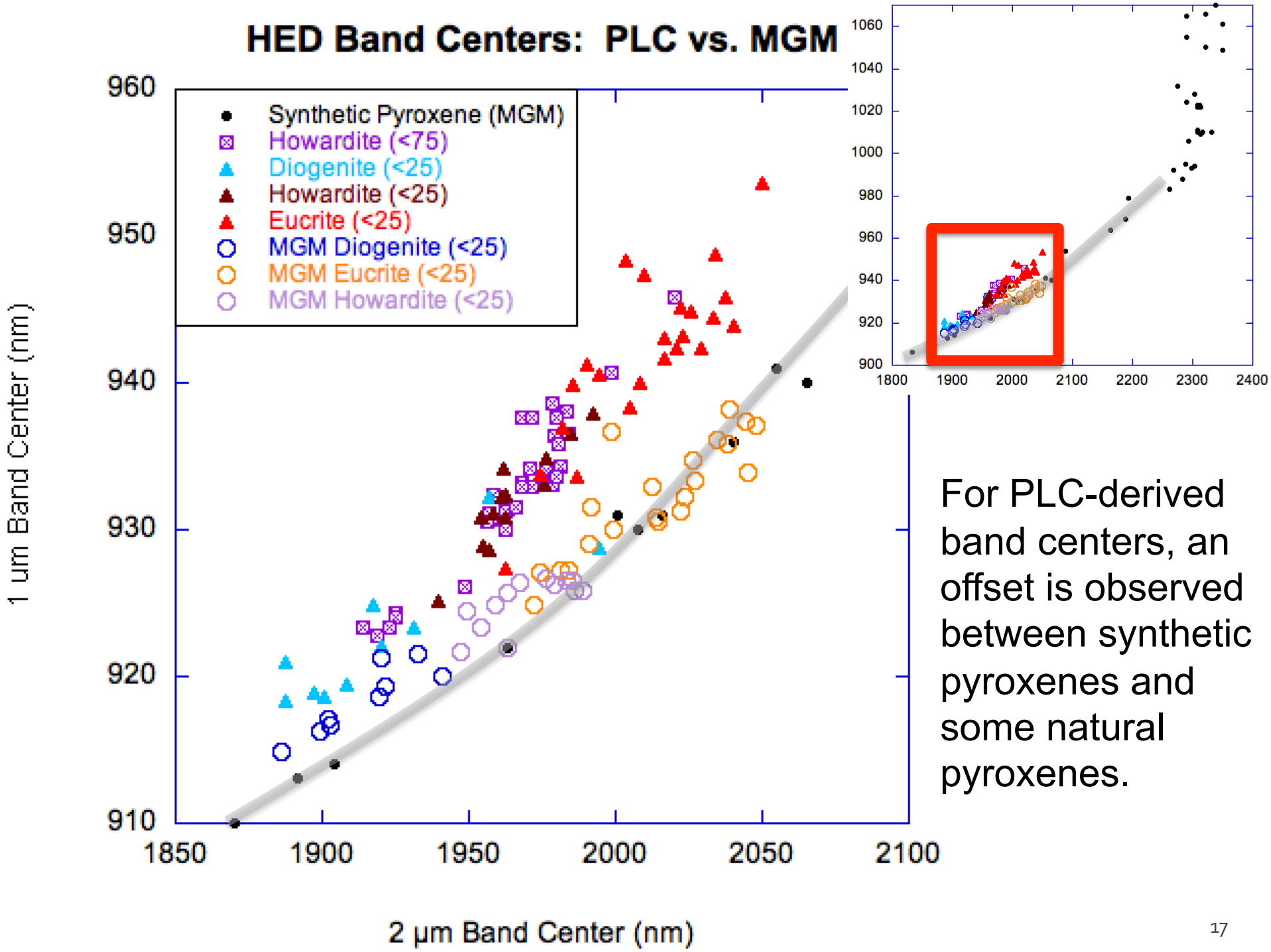
Spectral Parameters: Band Depth and Band Center





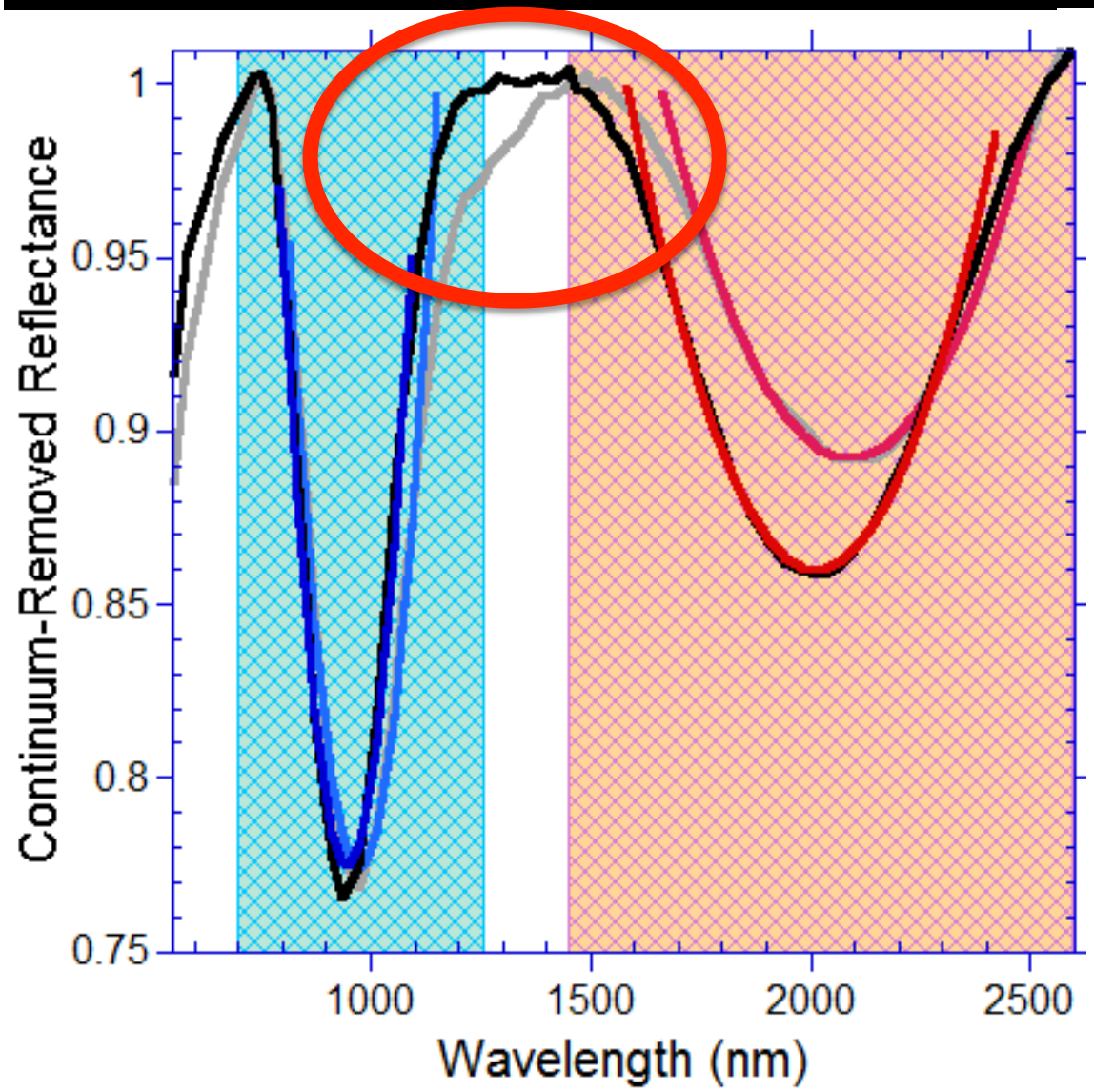
PLC band center measurements agree well with MGM results.





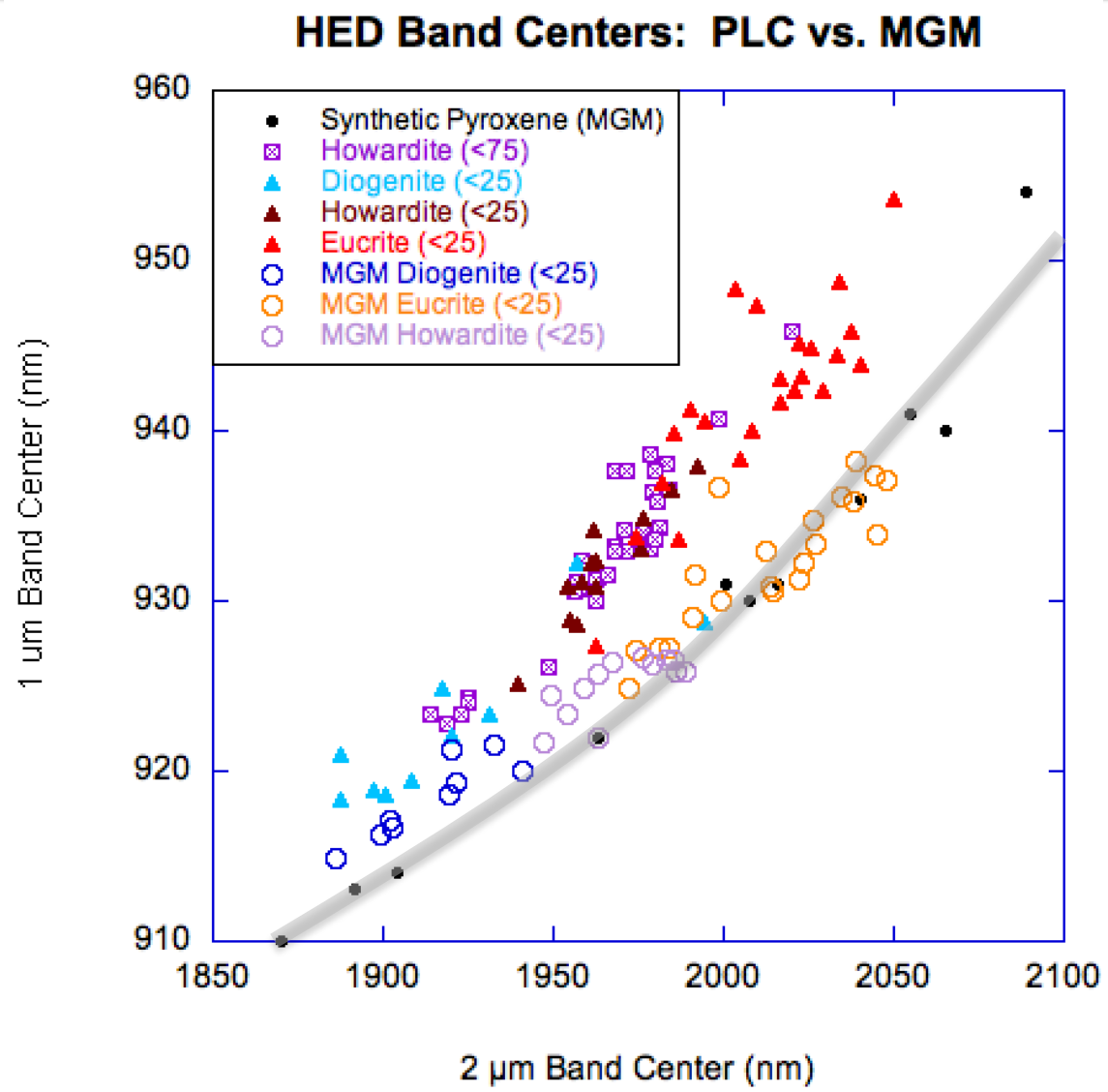
For PLC-derived band centers, an offset is observed between synthetic pyroxenes and some natural pyroxenes.

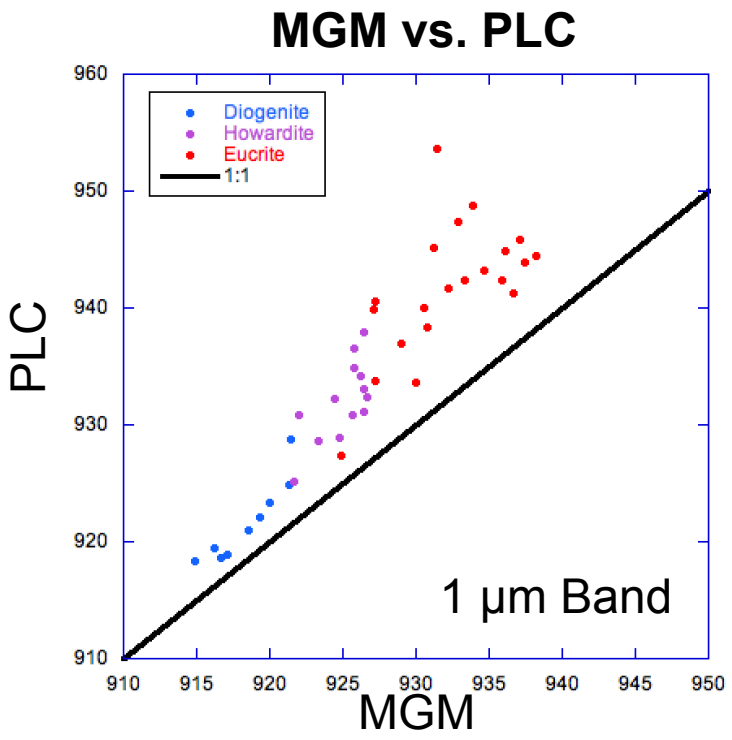
Effects of the 1.2 µm Band on PLC Fitting

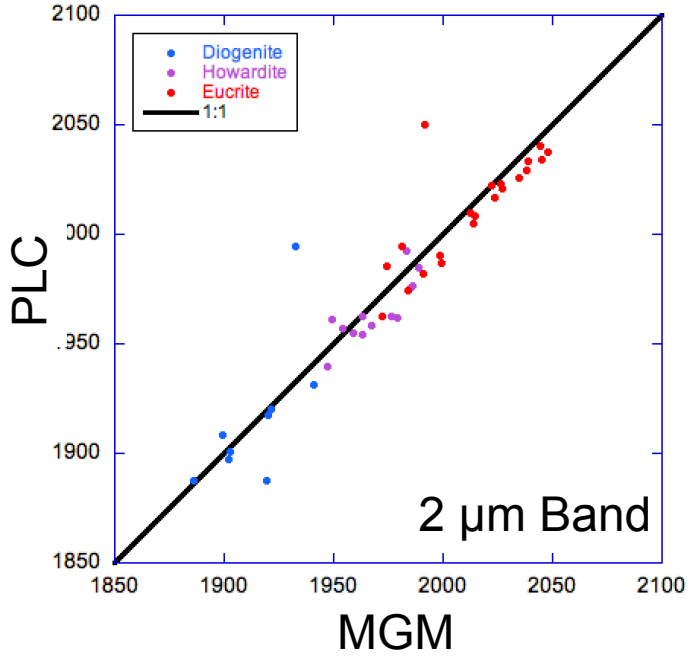


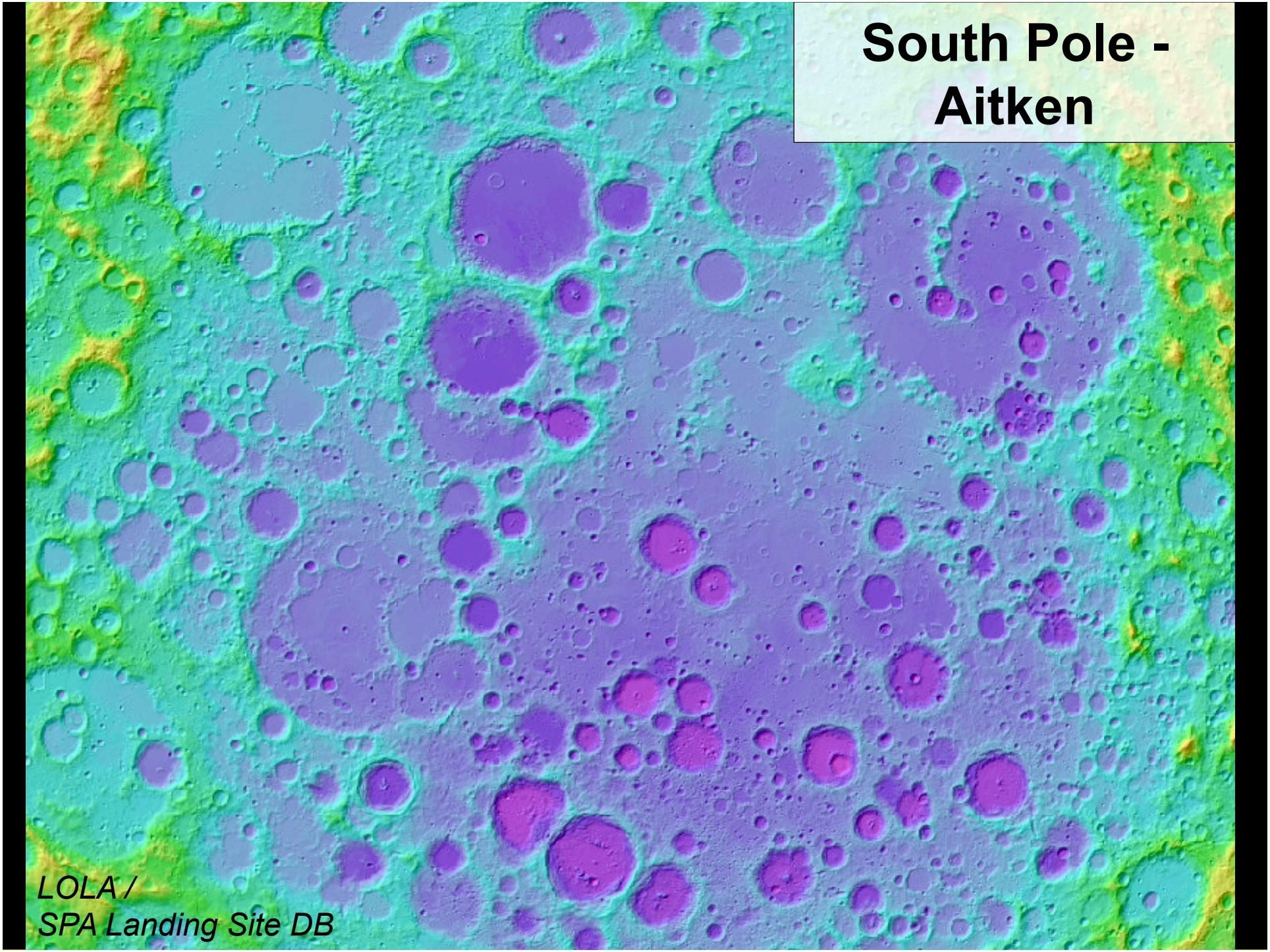
- PLC does not account for the 1.2 µm band.
- This can shift the PLC measurement of the 1 µm band to longer wavelengths.

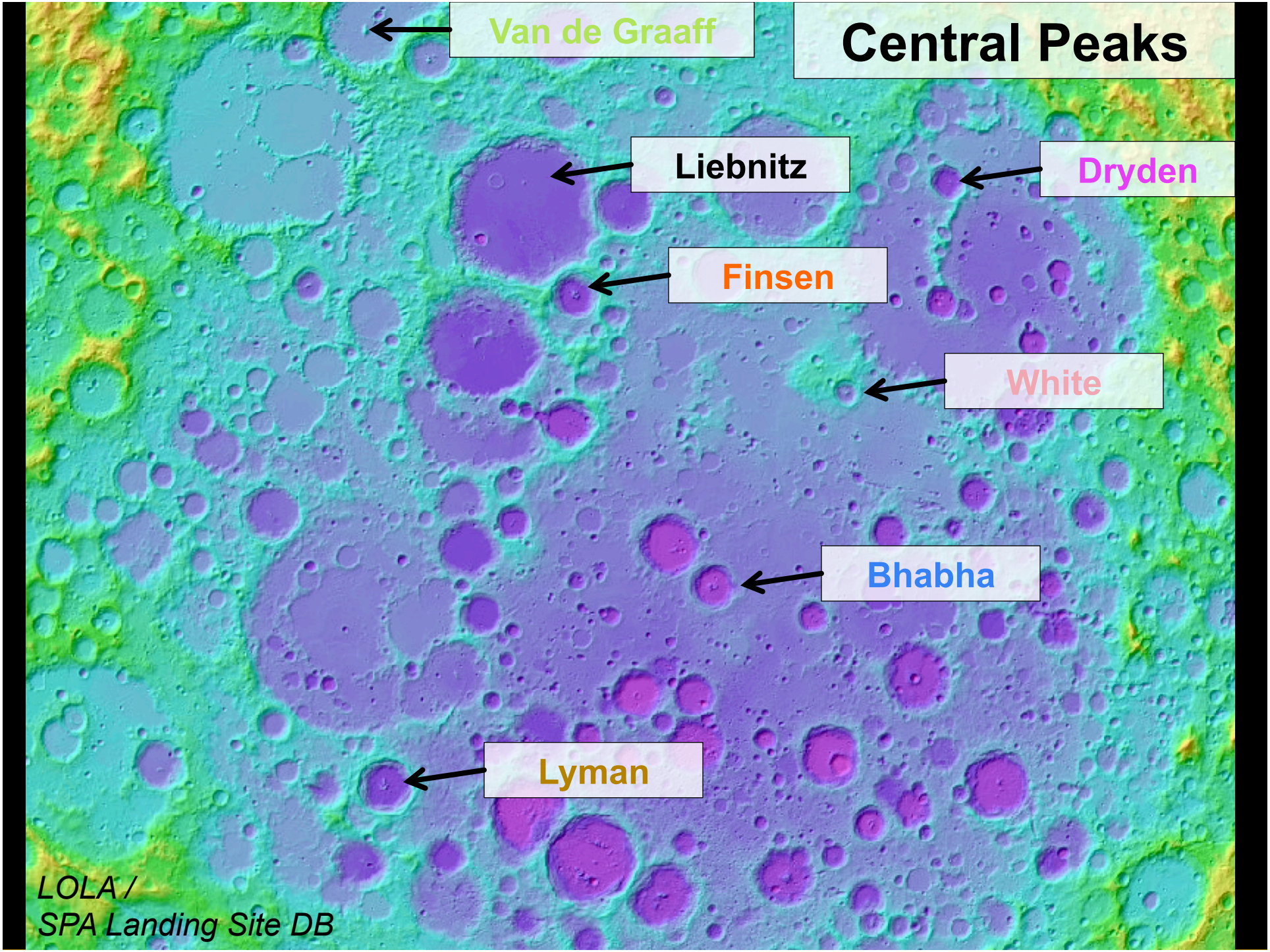
Effects of the 1.2 µm Band on PLC Fitting

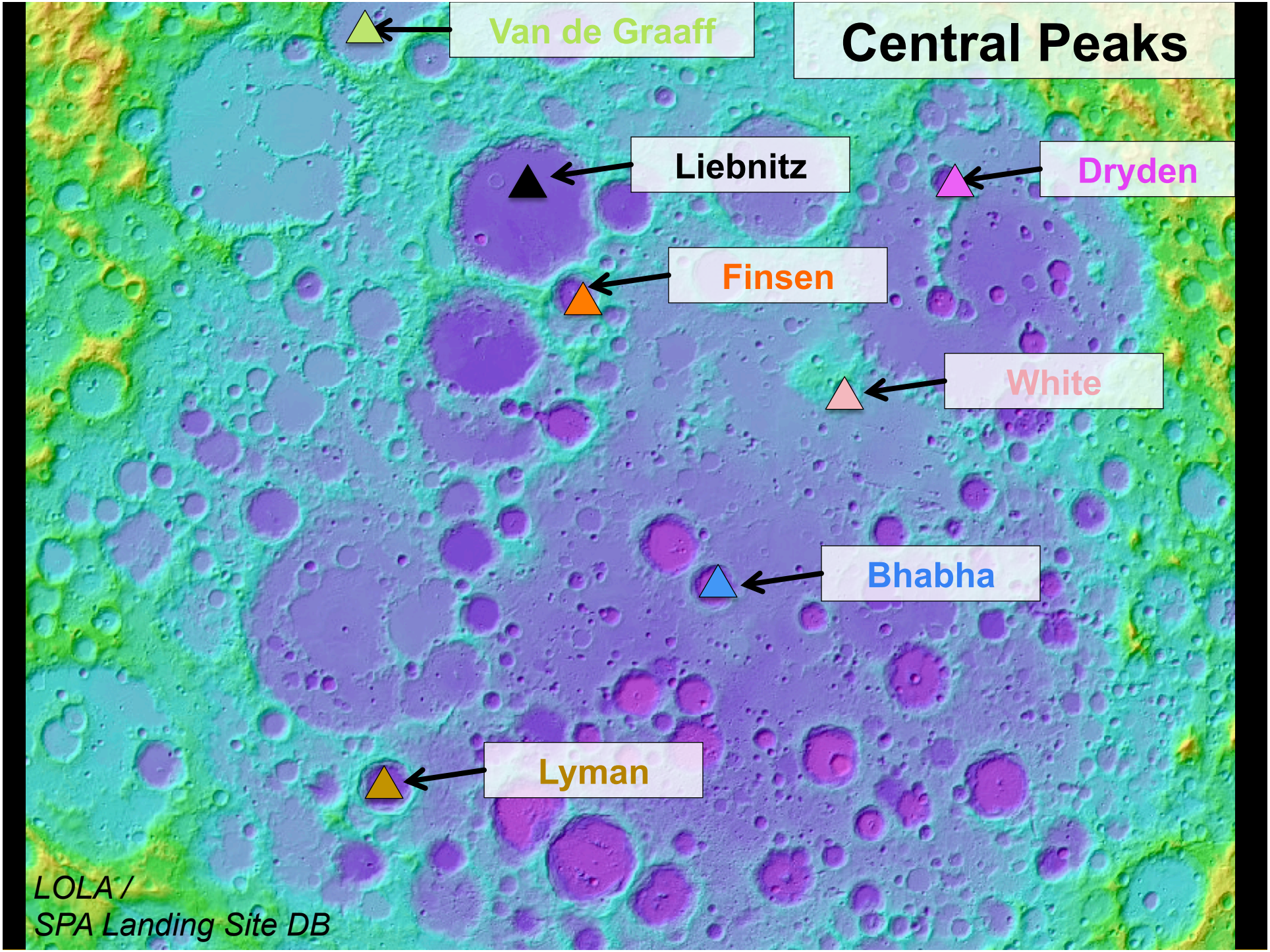







South Pole - Aitken
LOLA /
SPA Landing Site DB


Central Peaks
Van de Graaff
Liebnitz
Dryden
Finsen
White
Bhabha
Lyman
LOLA /
SPA Landing Site DB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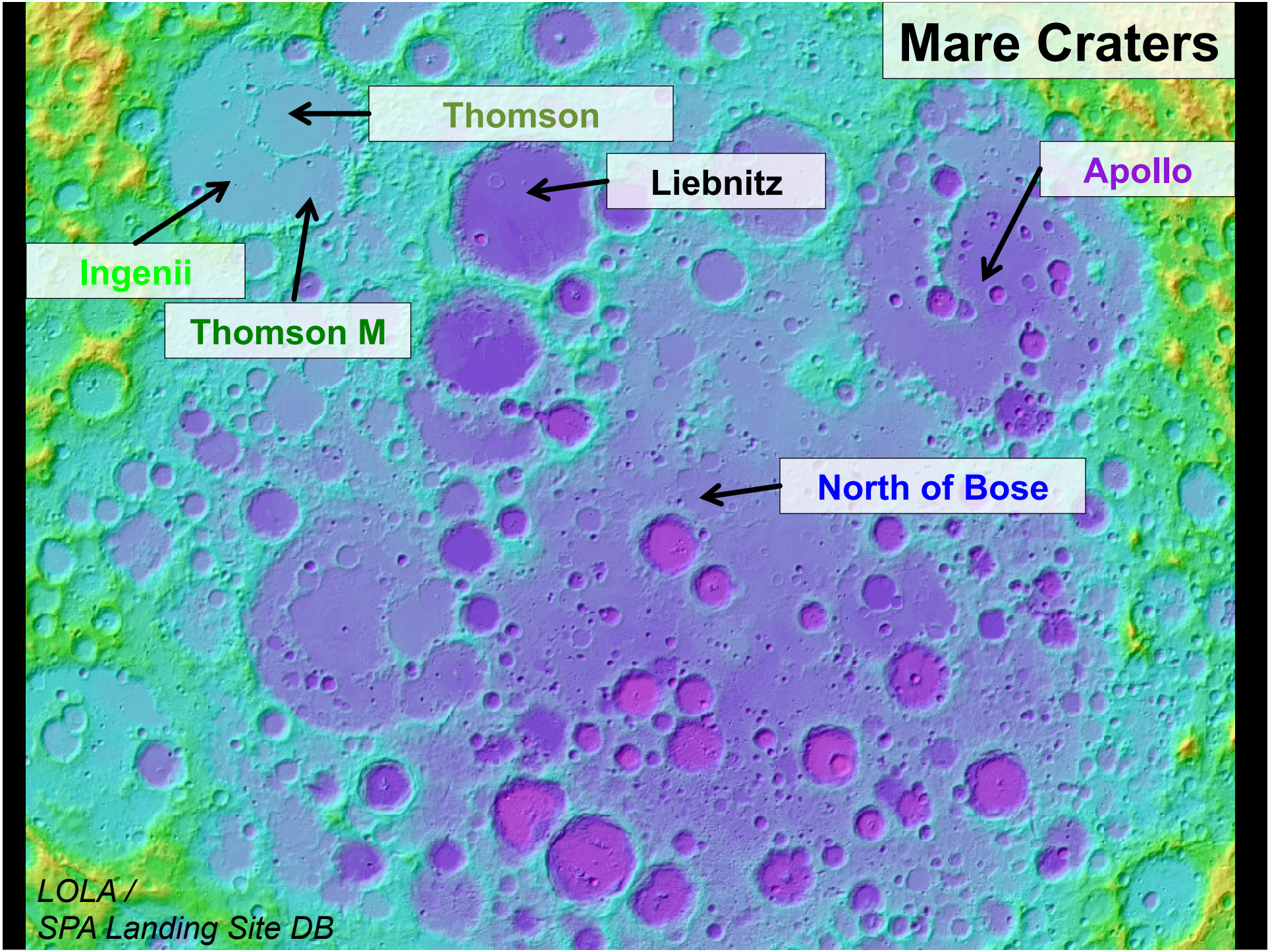
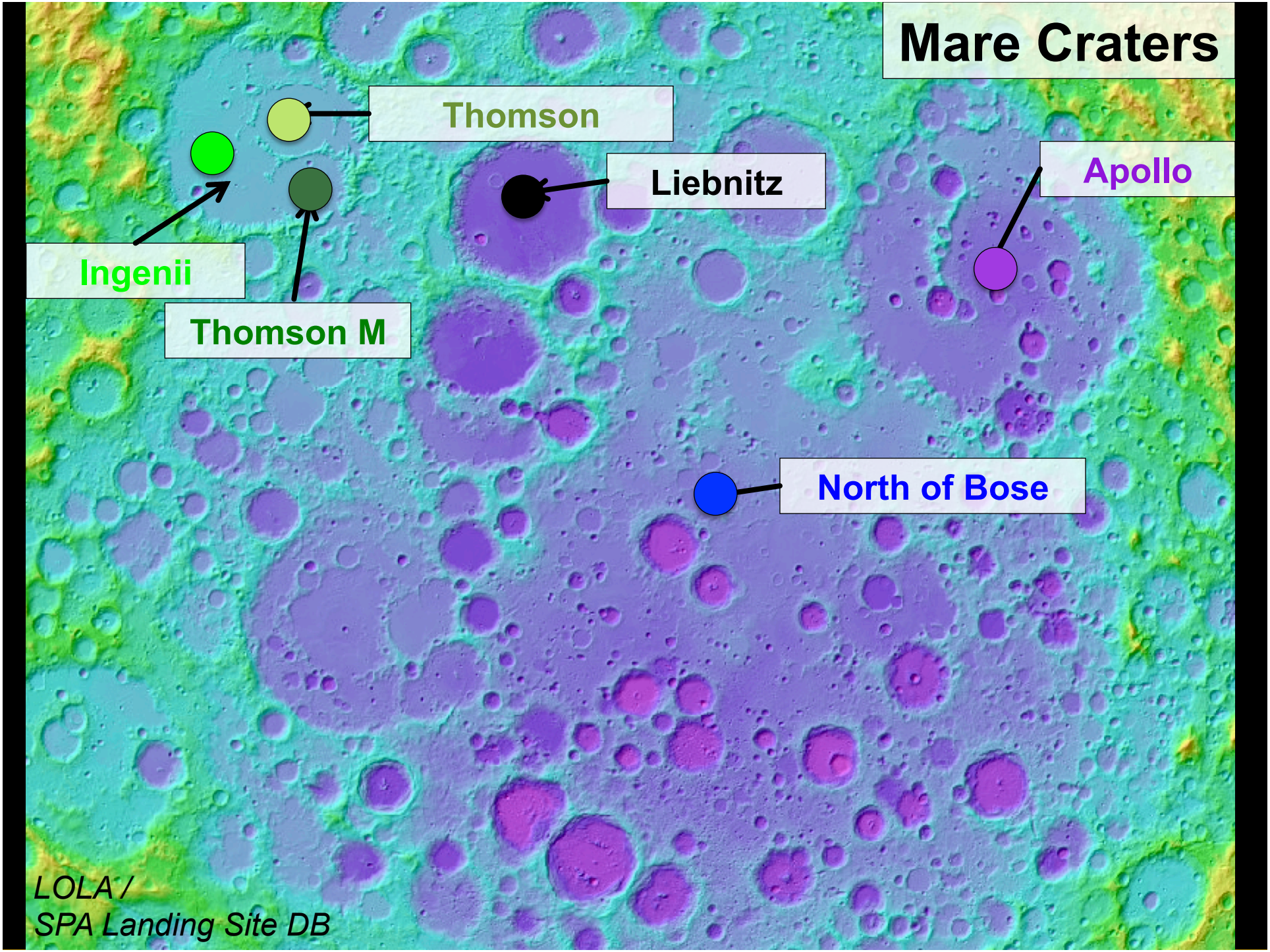

Mare Craters
Thomson
Liebnitz
Apollo
Ingenii
Thomson M
North of Bose
LOLA /
SPA Landing Site DB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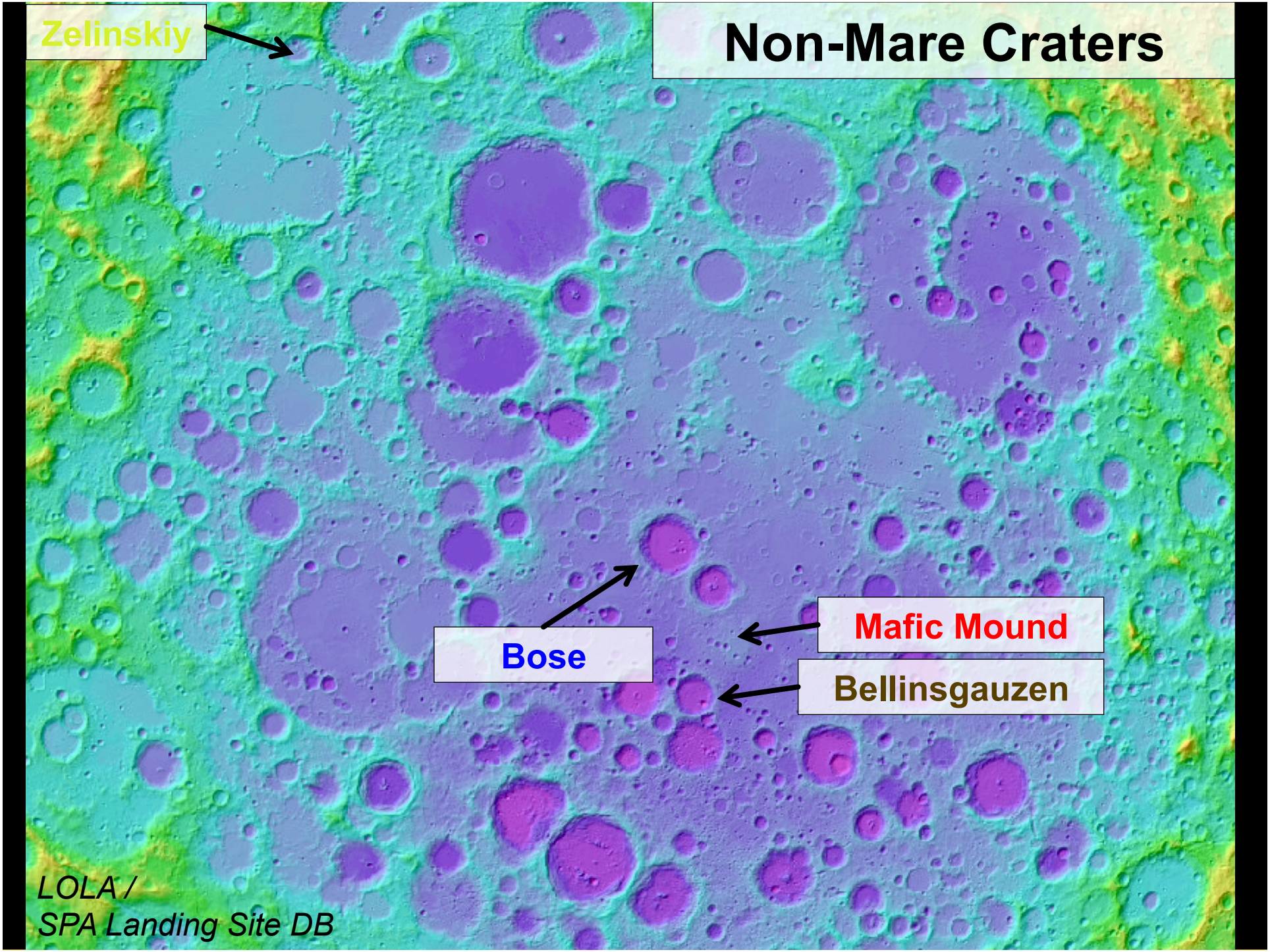
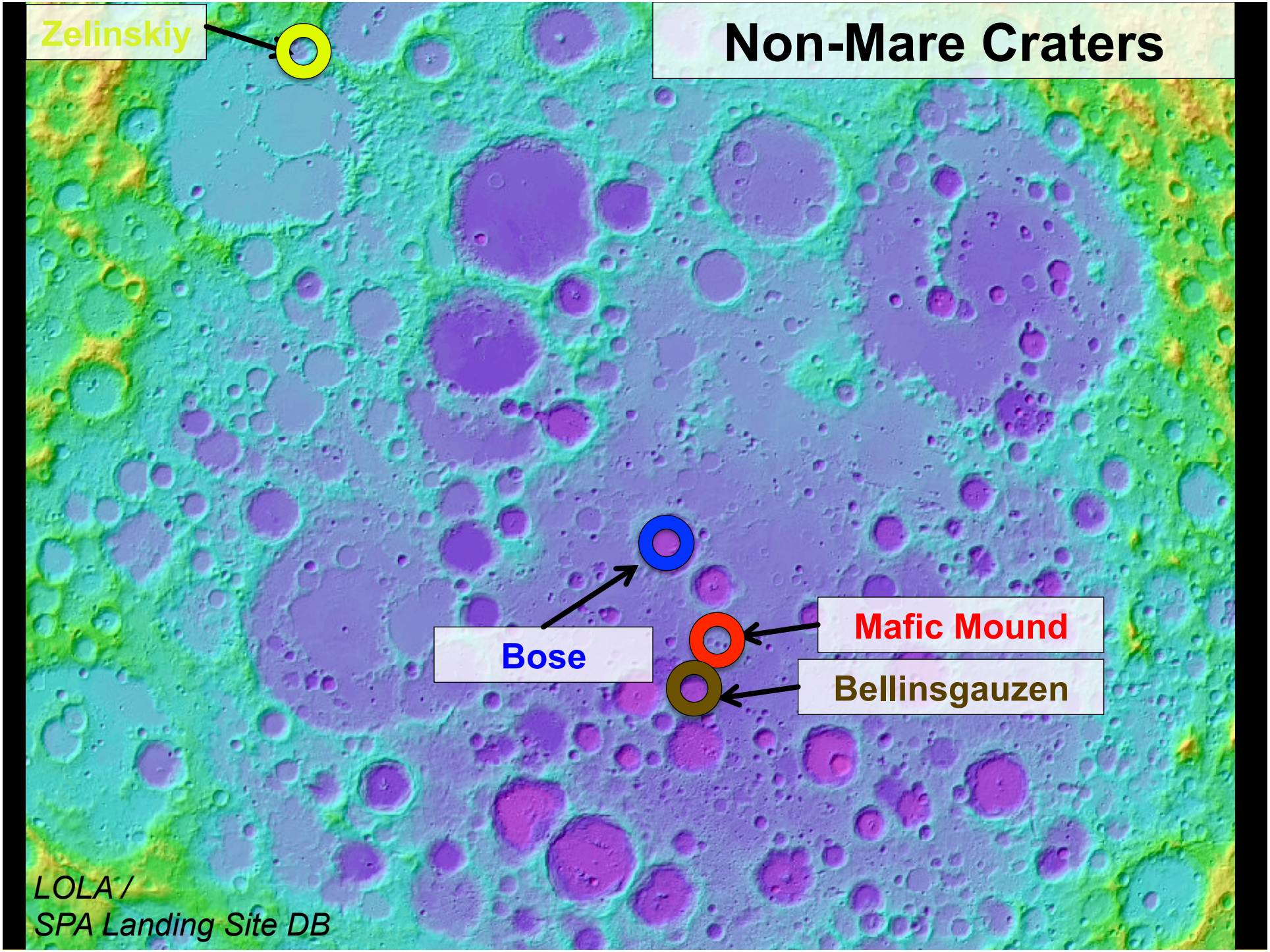

Non-Mare Craters
Zelinskiy
Bose
Mafic Mound
Bellinsgauzen
LOLA /
SPA Landing Site DB


Zelinskiy
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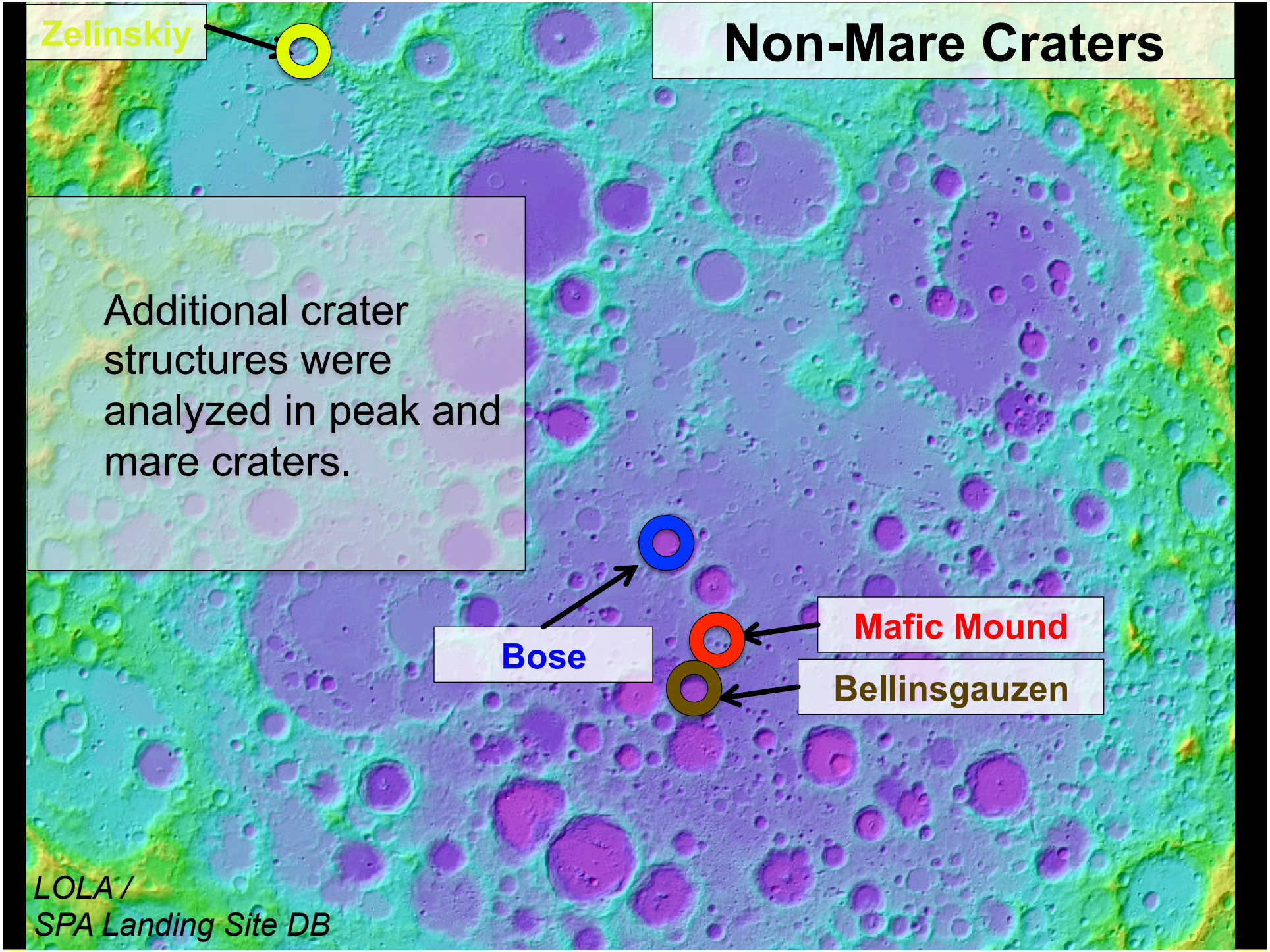
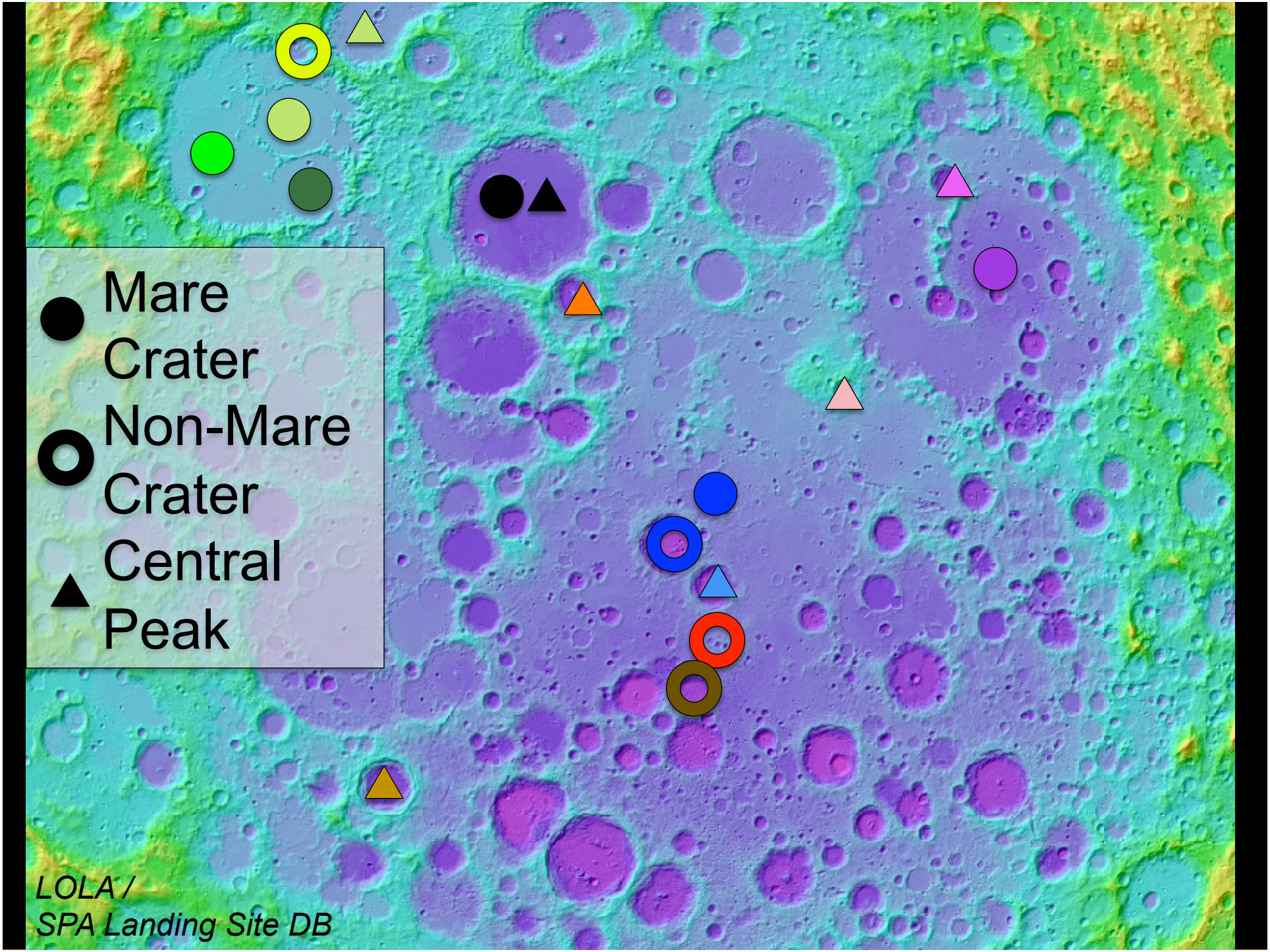
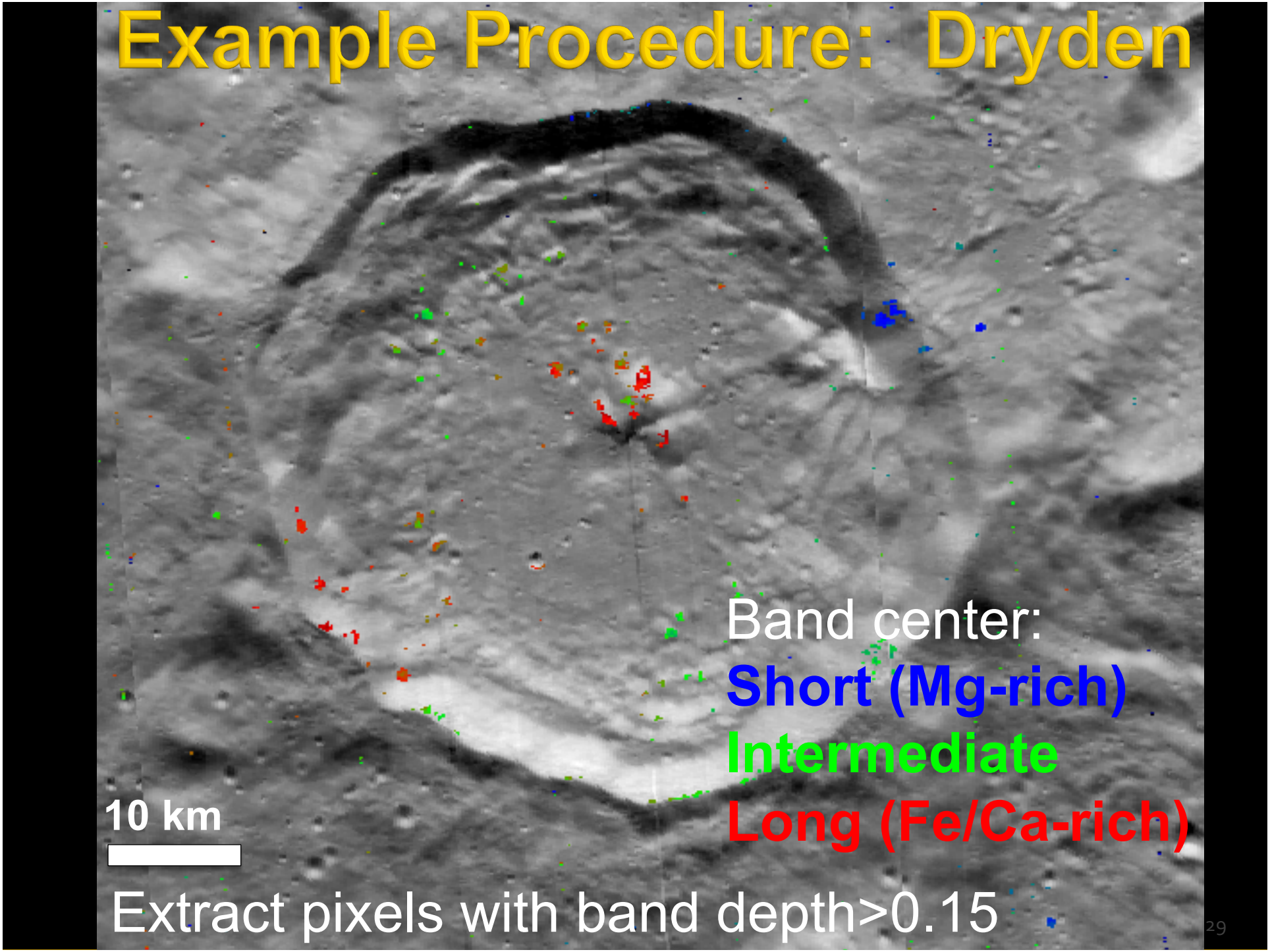

Zelinskiy
Non-Mare Craters
Additional crater structures were analyzed in peak and mare craters.
Bose
Mafic Mound
Bellinsgauzen
LOLA /
SPA Landing Site DB

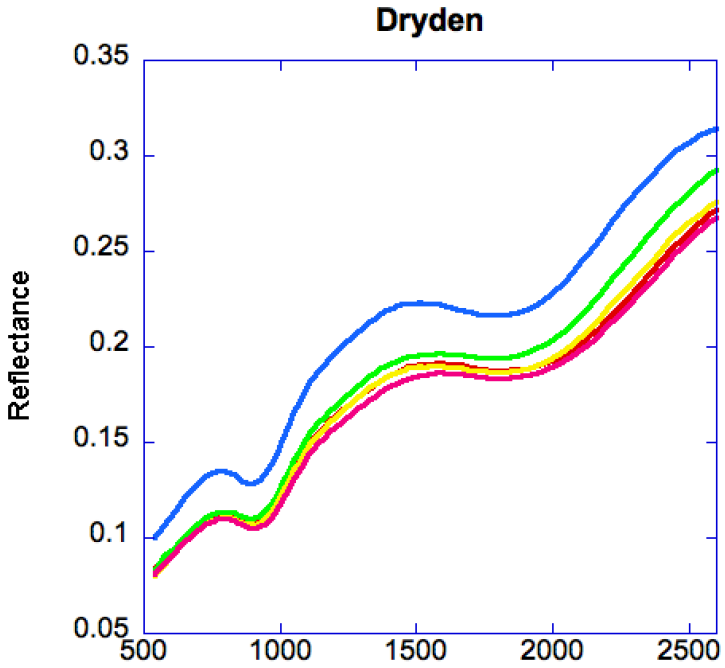

Mare Crater
Non-Mare Crater
Central Peak
LOLA /
SPA Landing Site DB

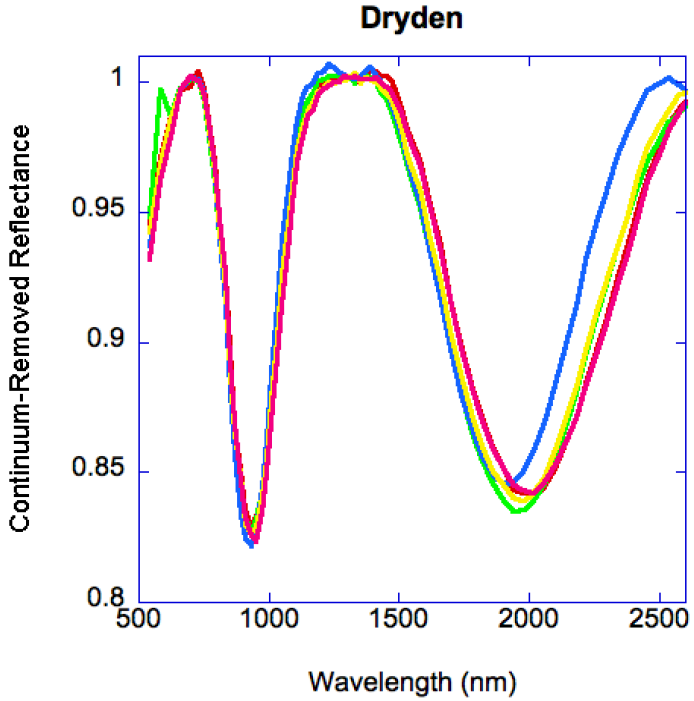
Example Procedure: Dryden

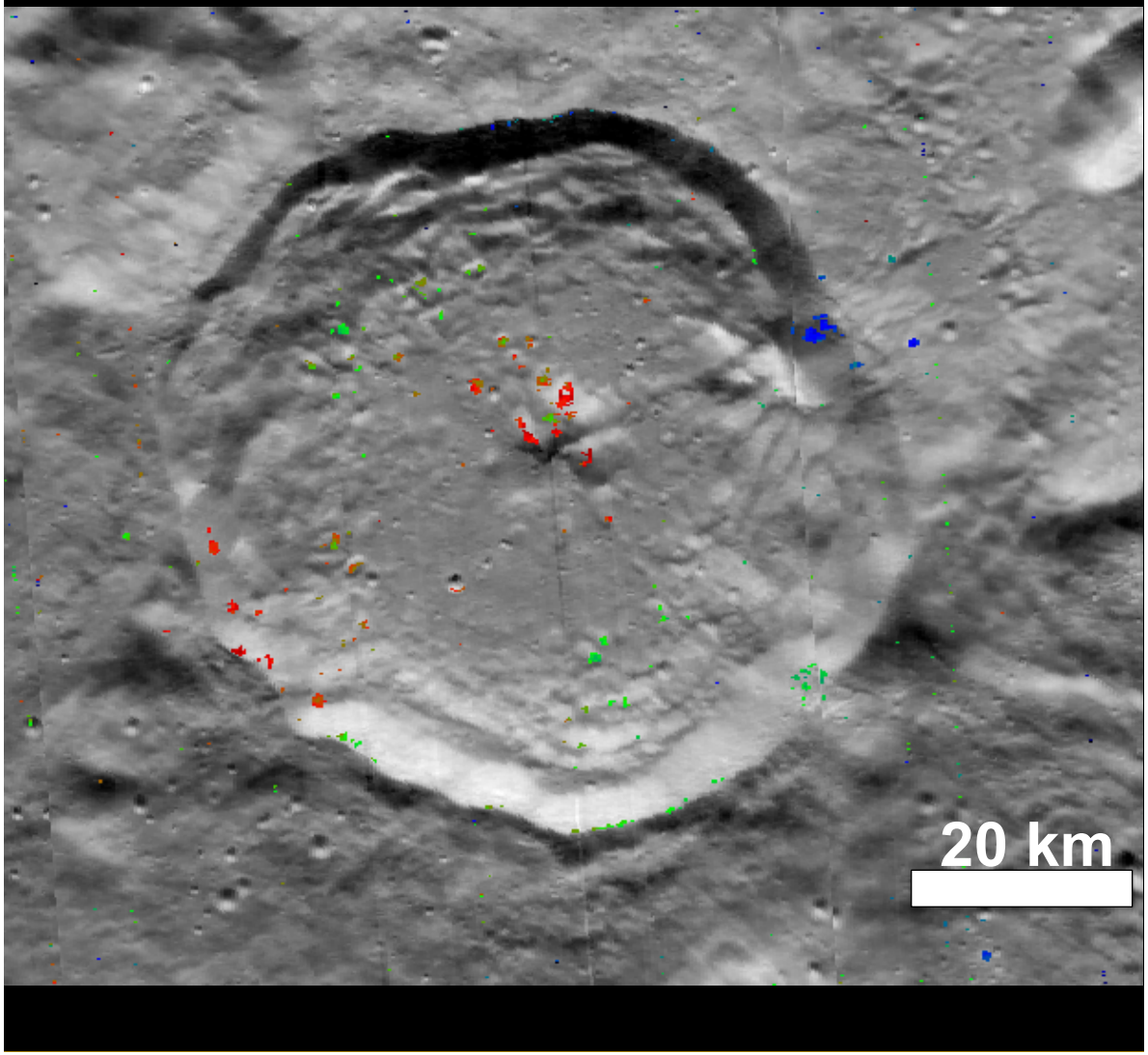


Extract pixels with band depth>0.15

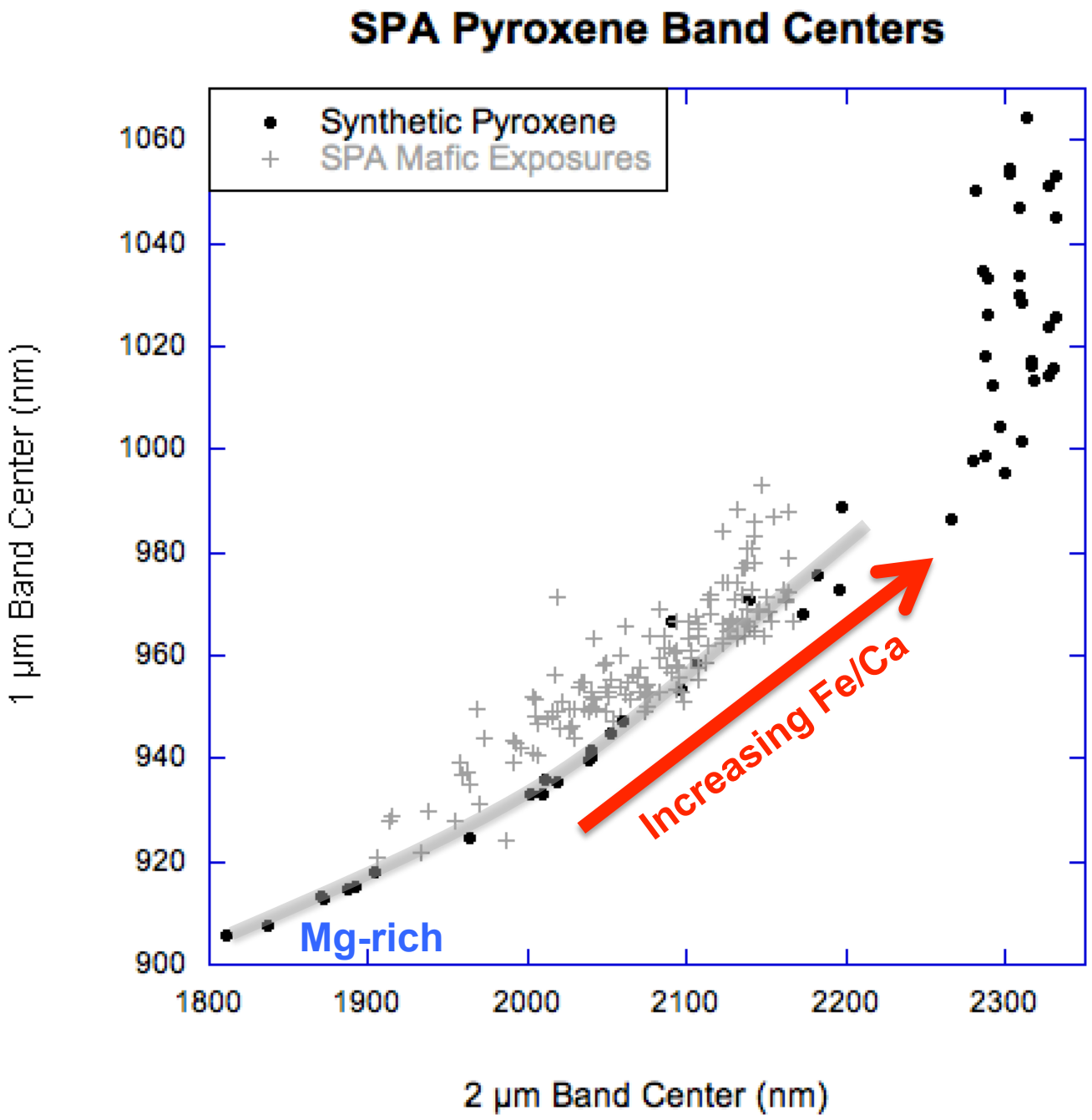
Average Spectra





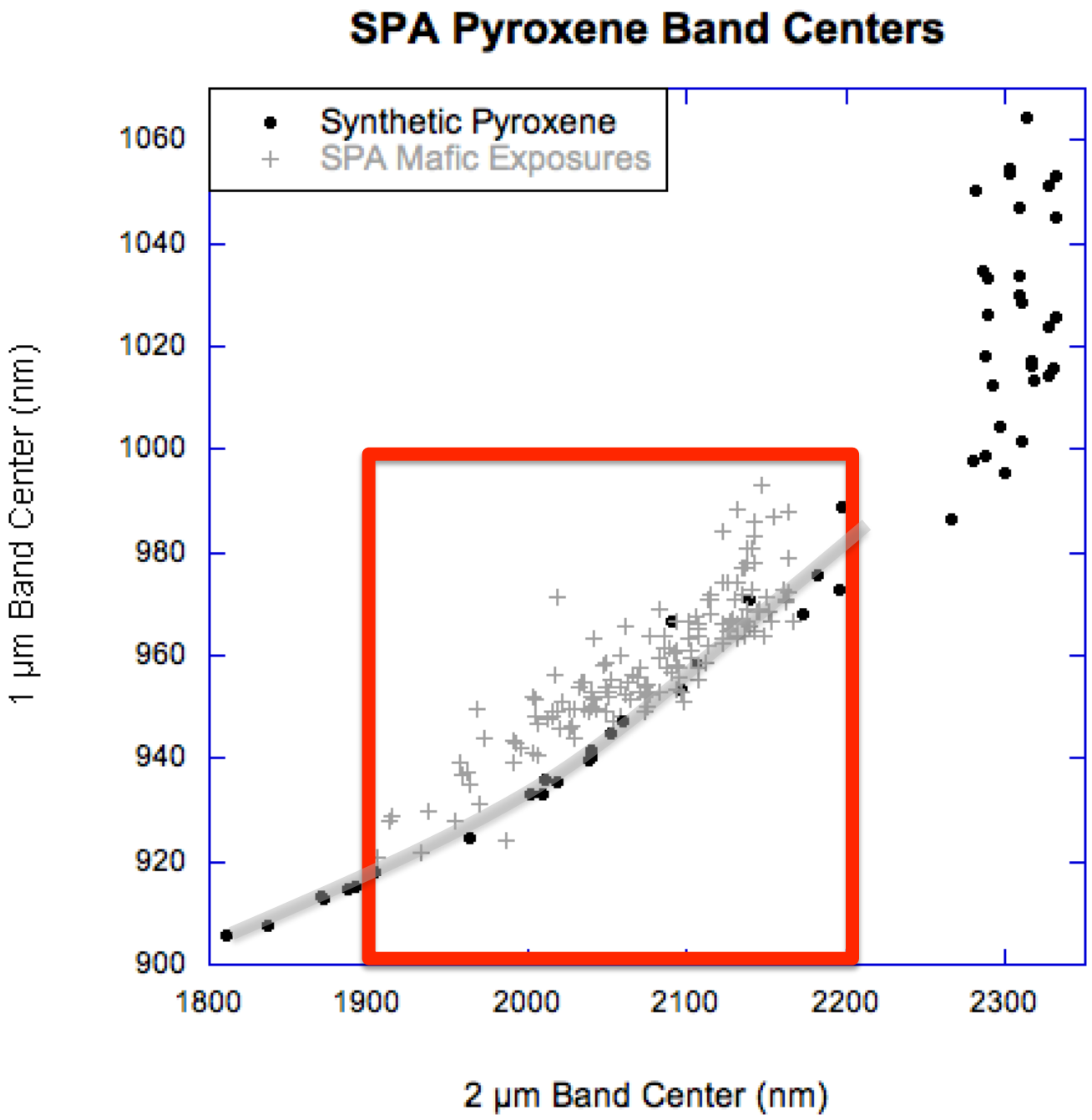


All Subregions



- SPA materials follow the general pyroxene trend.
- Significant diversity in pyroxene composition is observed.
- The observed offset from the synthetic pyroxene trend may result from the presence of a 1.2 µm band.

All Subregions



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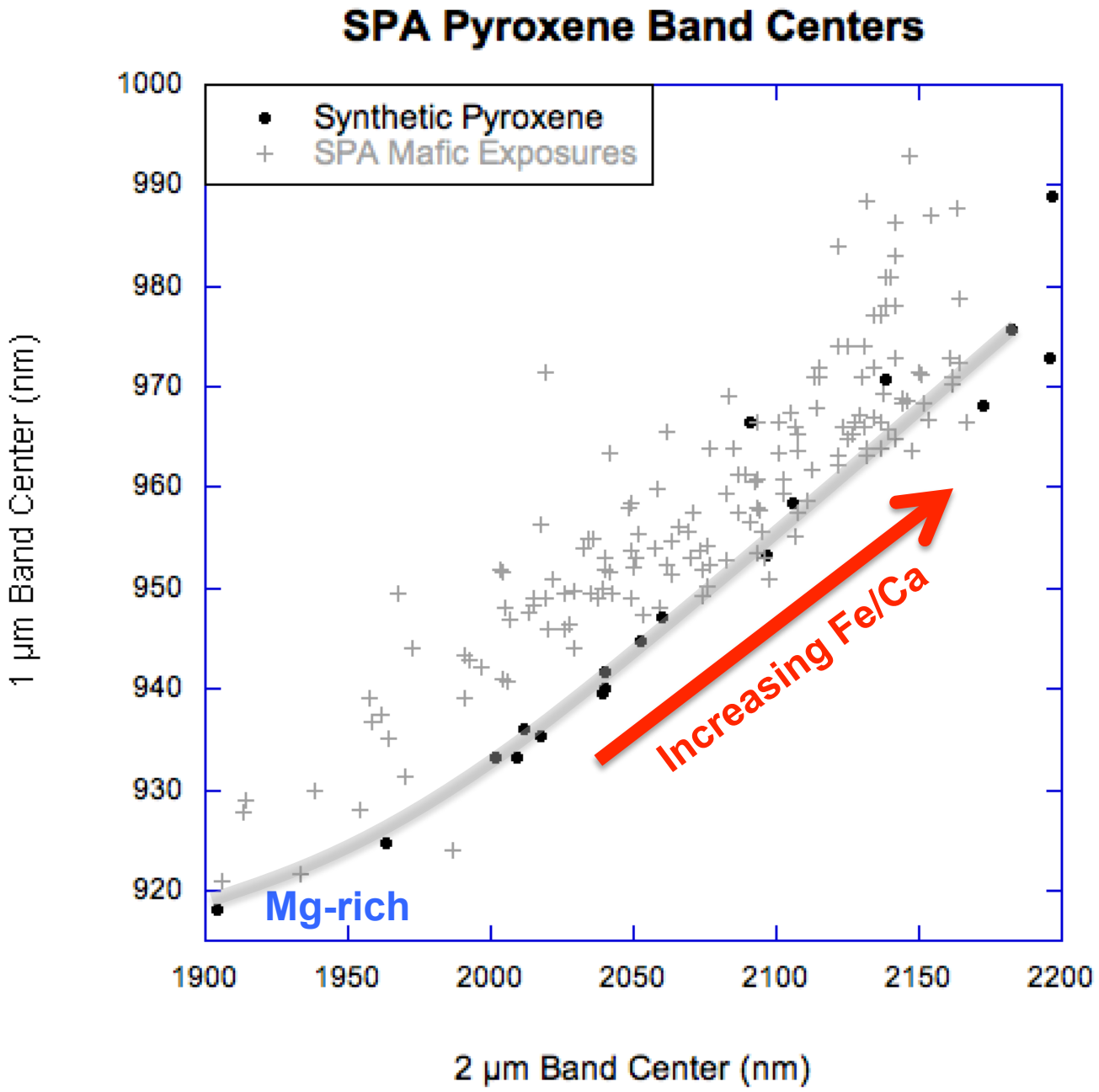

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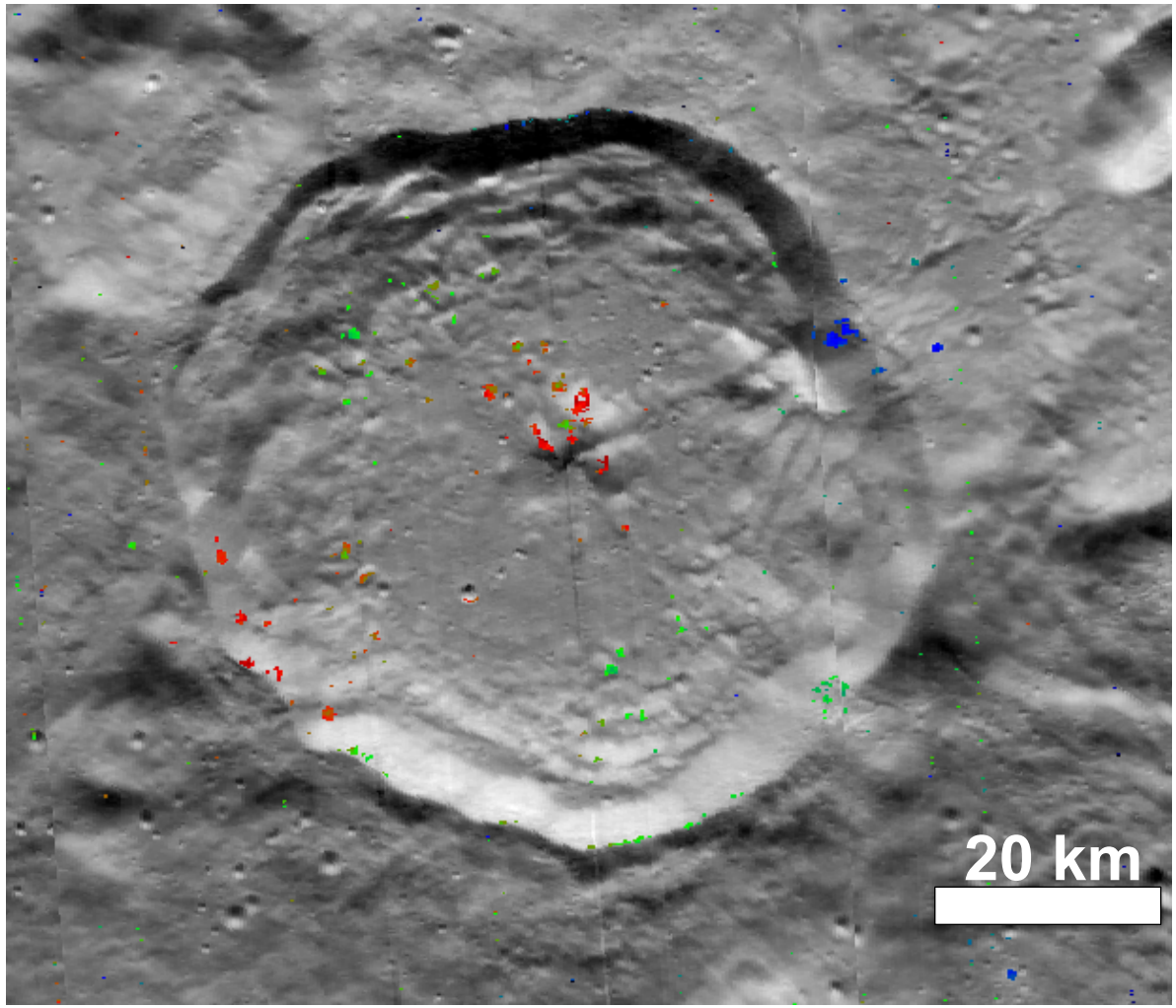
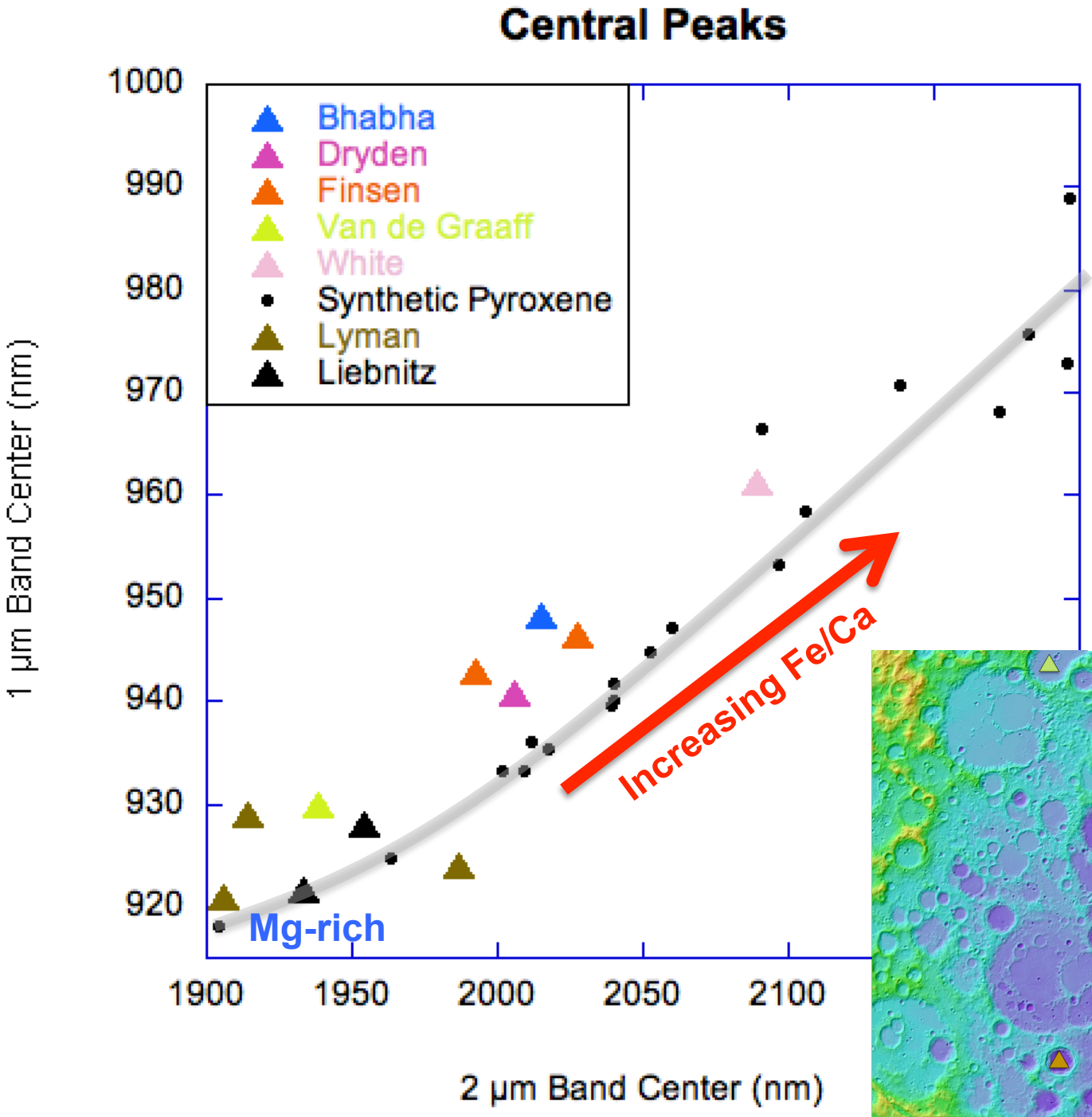
Central Peaks

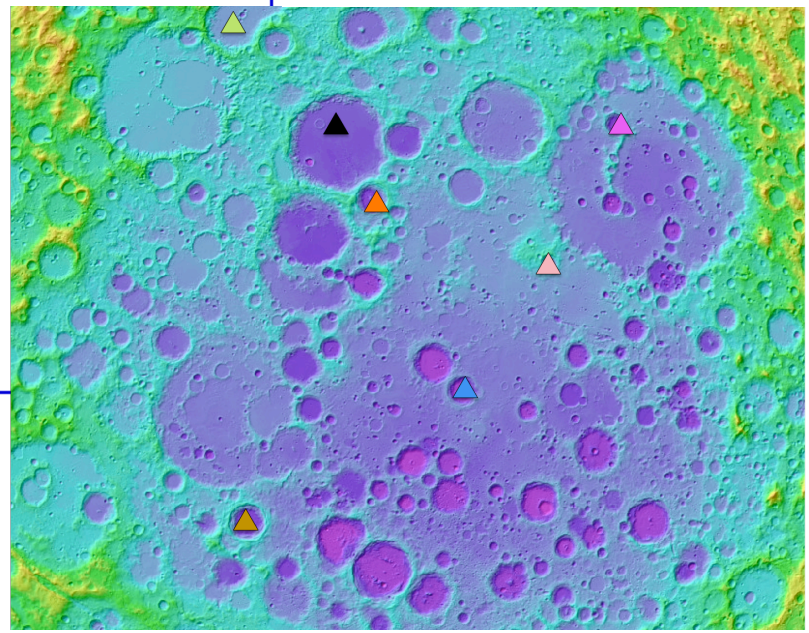
- The central peaks in this study have uplifted material from ~10 km.
- Central peaks may be relatively unaffected by soil development.

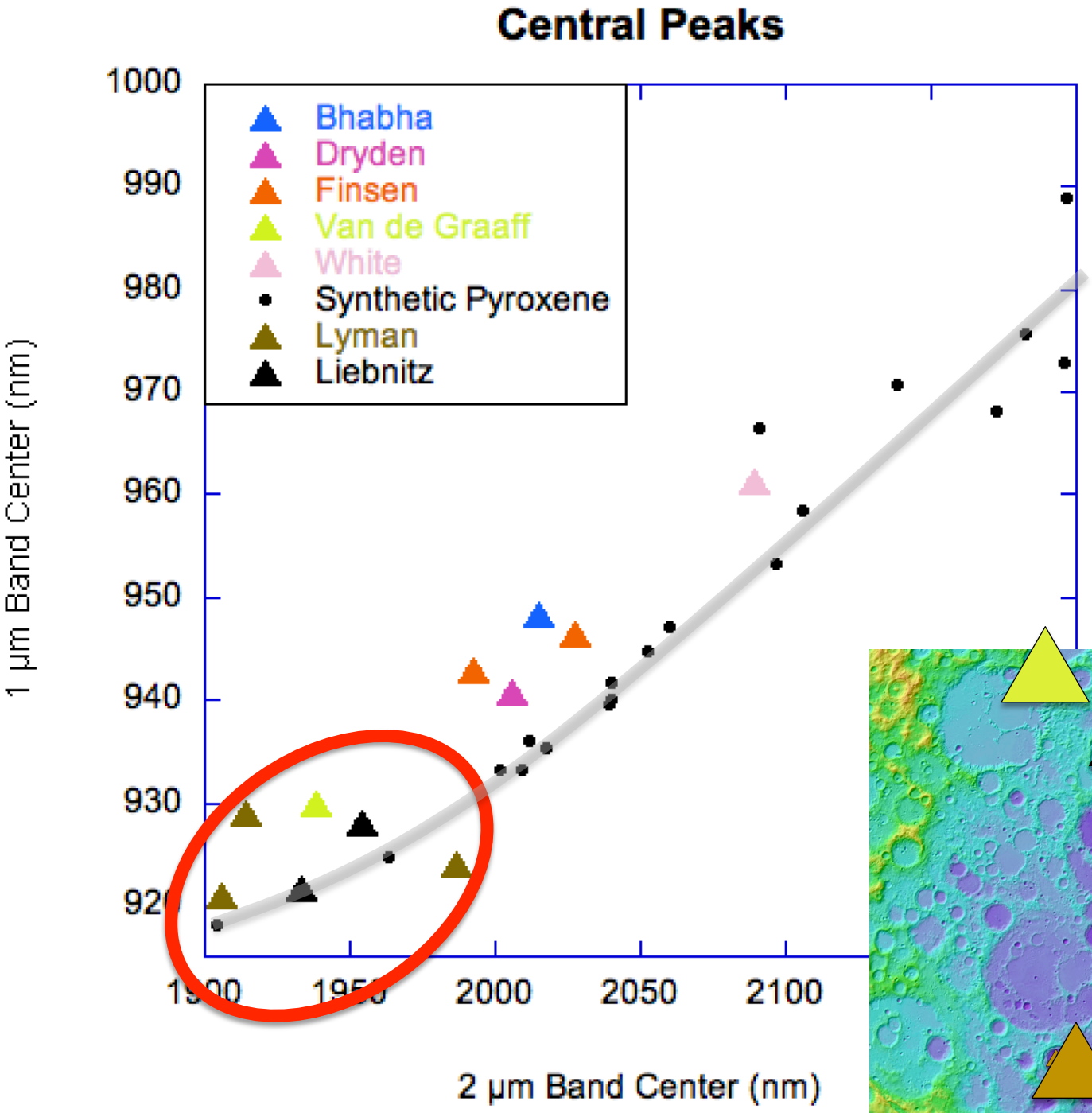




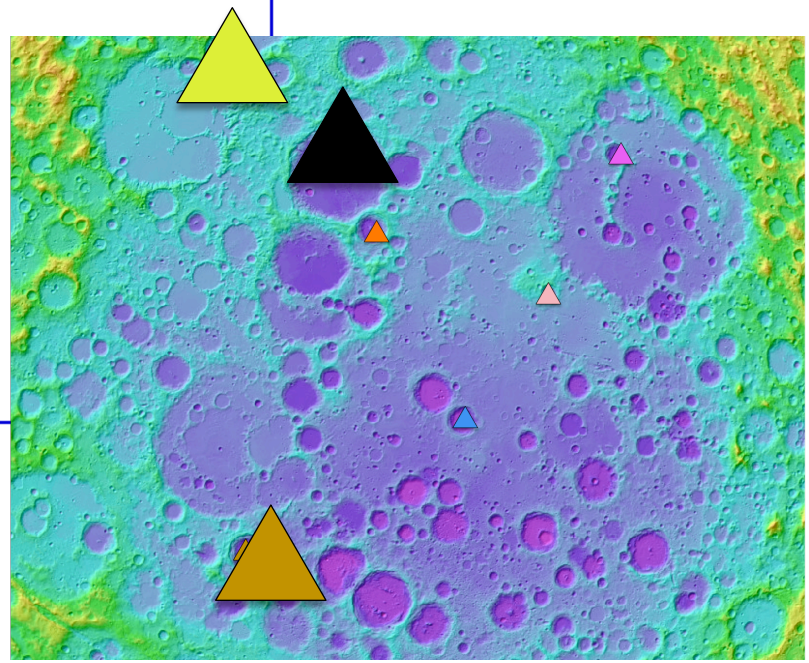
Central peaks are dominated by Mg-rich pyroxenes.

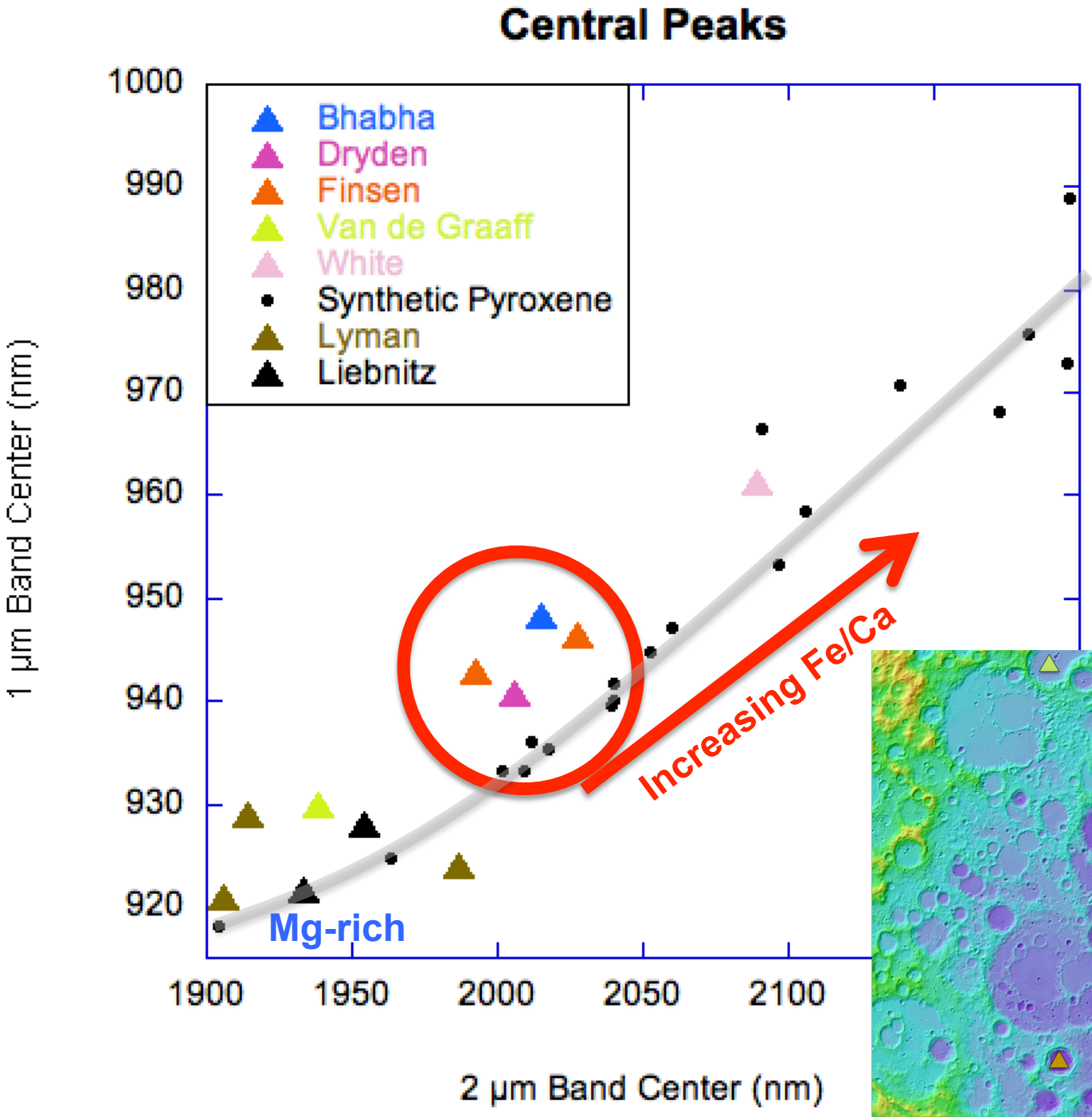
The observed central peak compositions fall into two clusters.



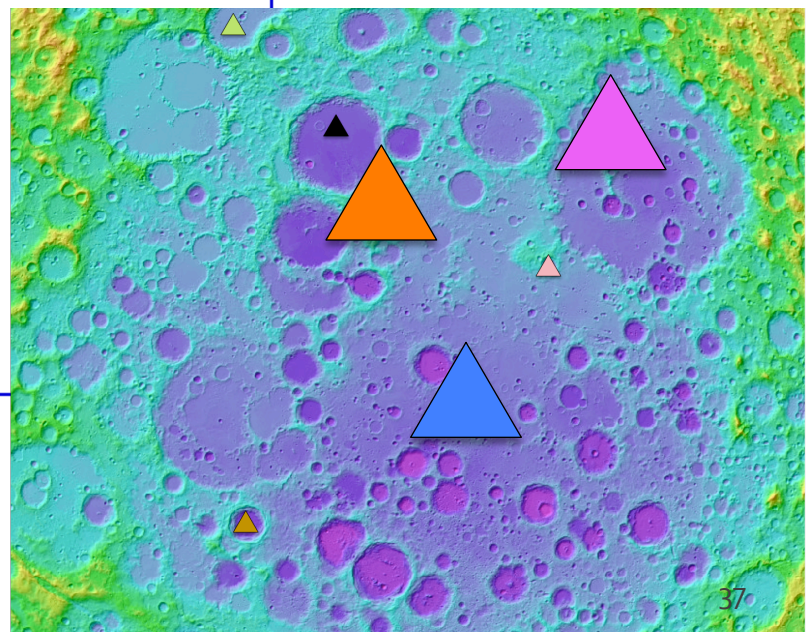


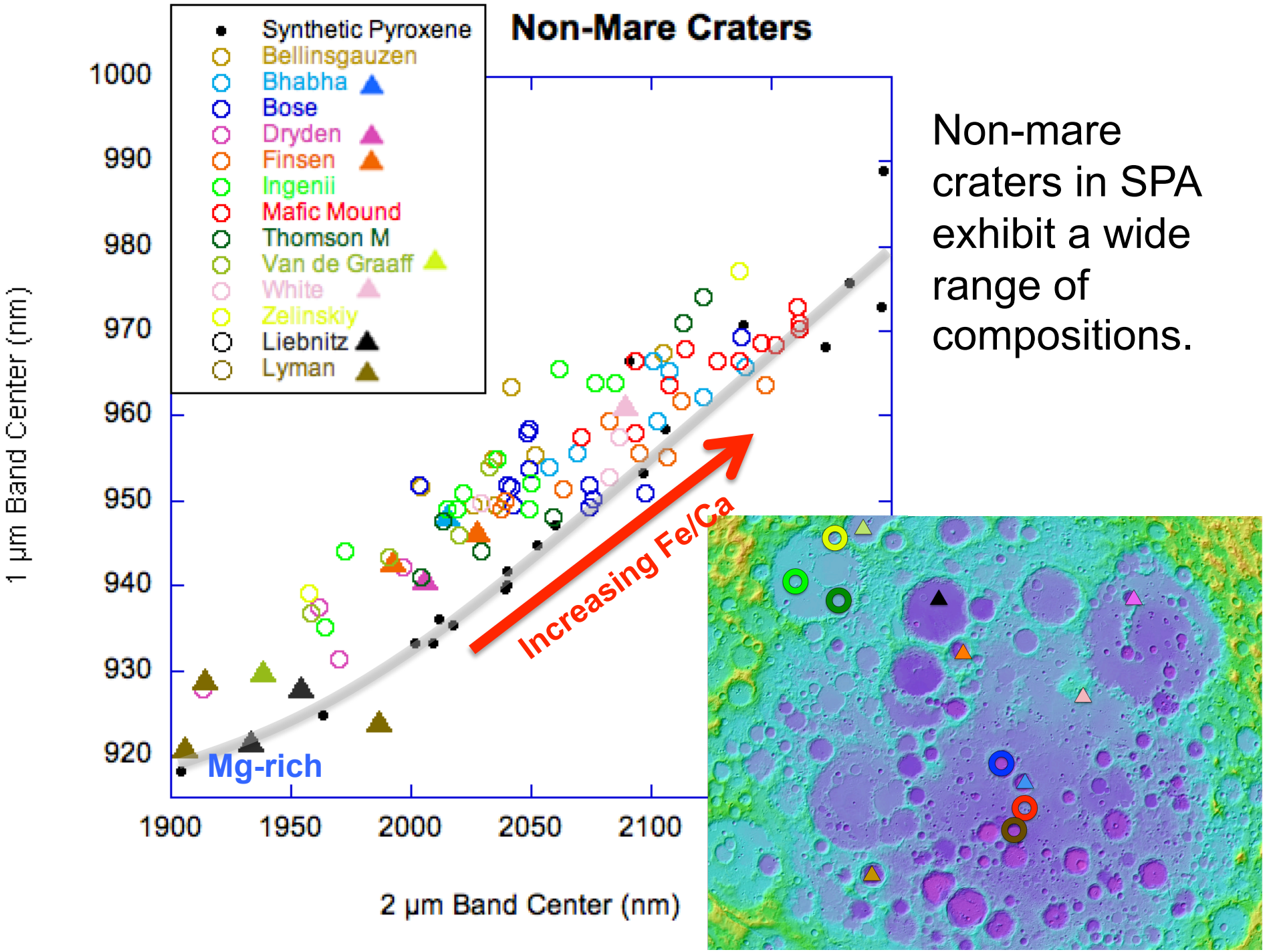
The short-wavelength cluster is dominated by very Mg-rich pyroxenes.



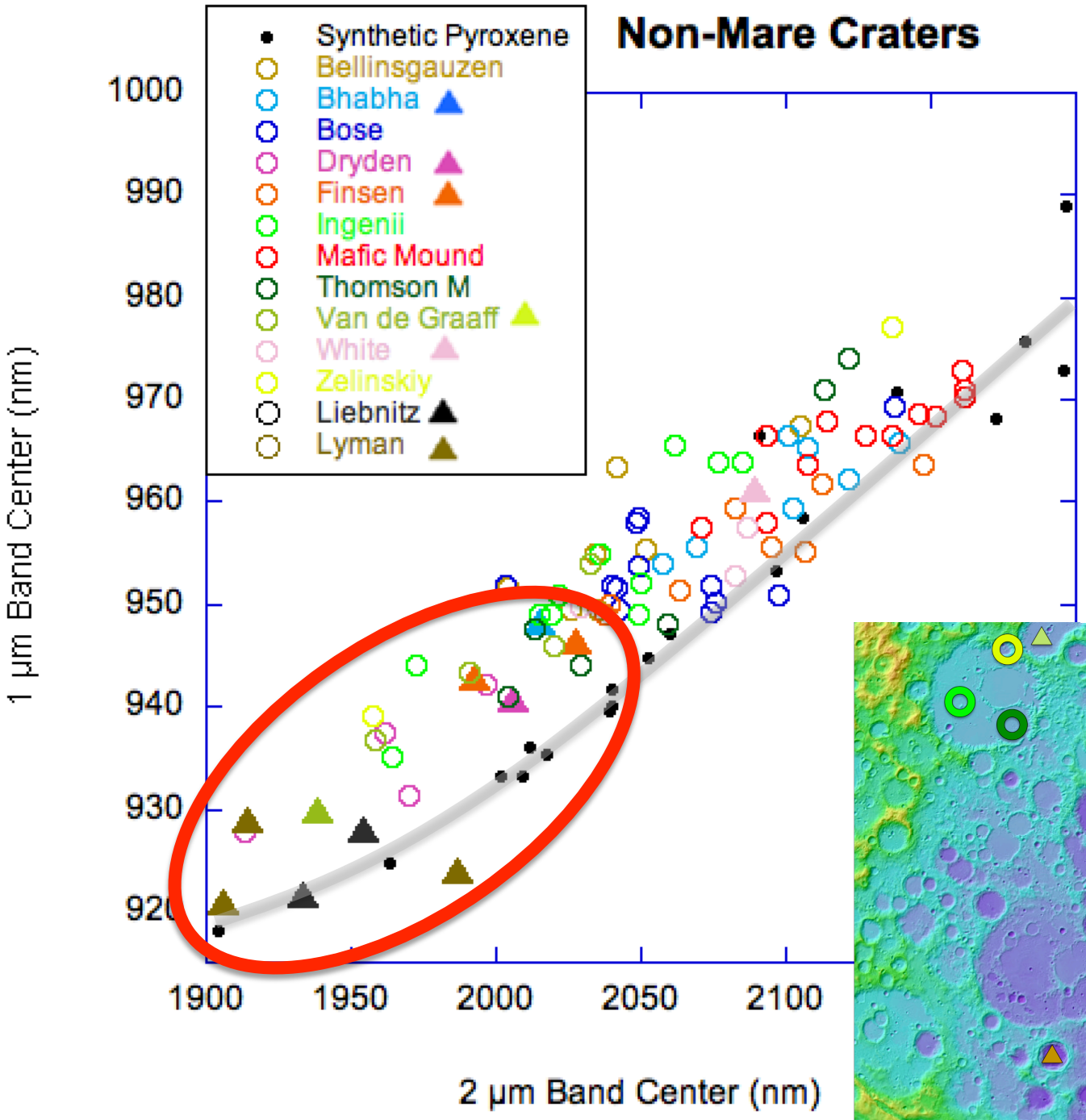


The intermediate-wavelength cluster is dominated by pyroxenes somewhat richer in Fe/Ca.

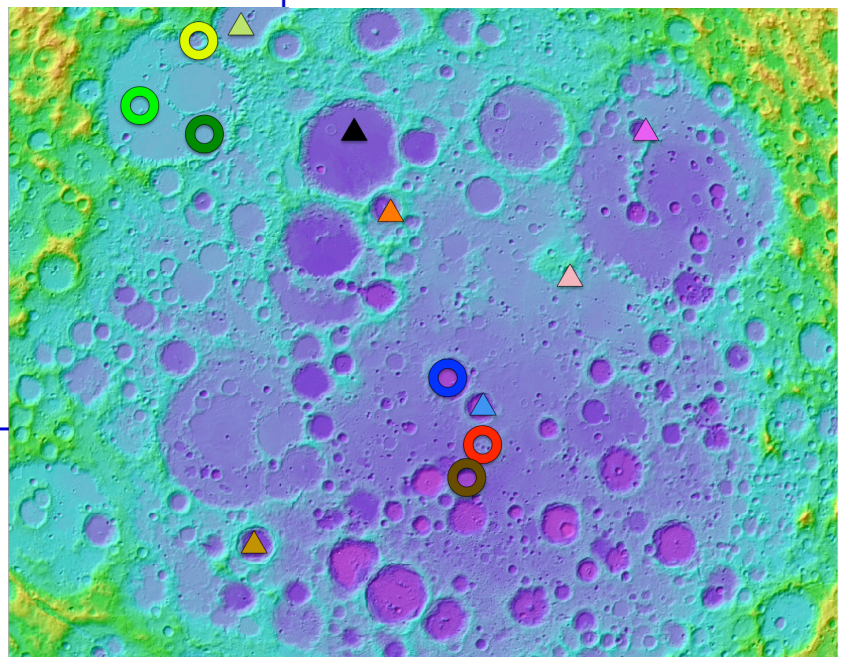


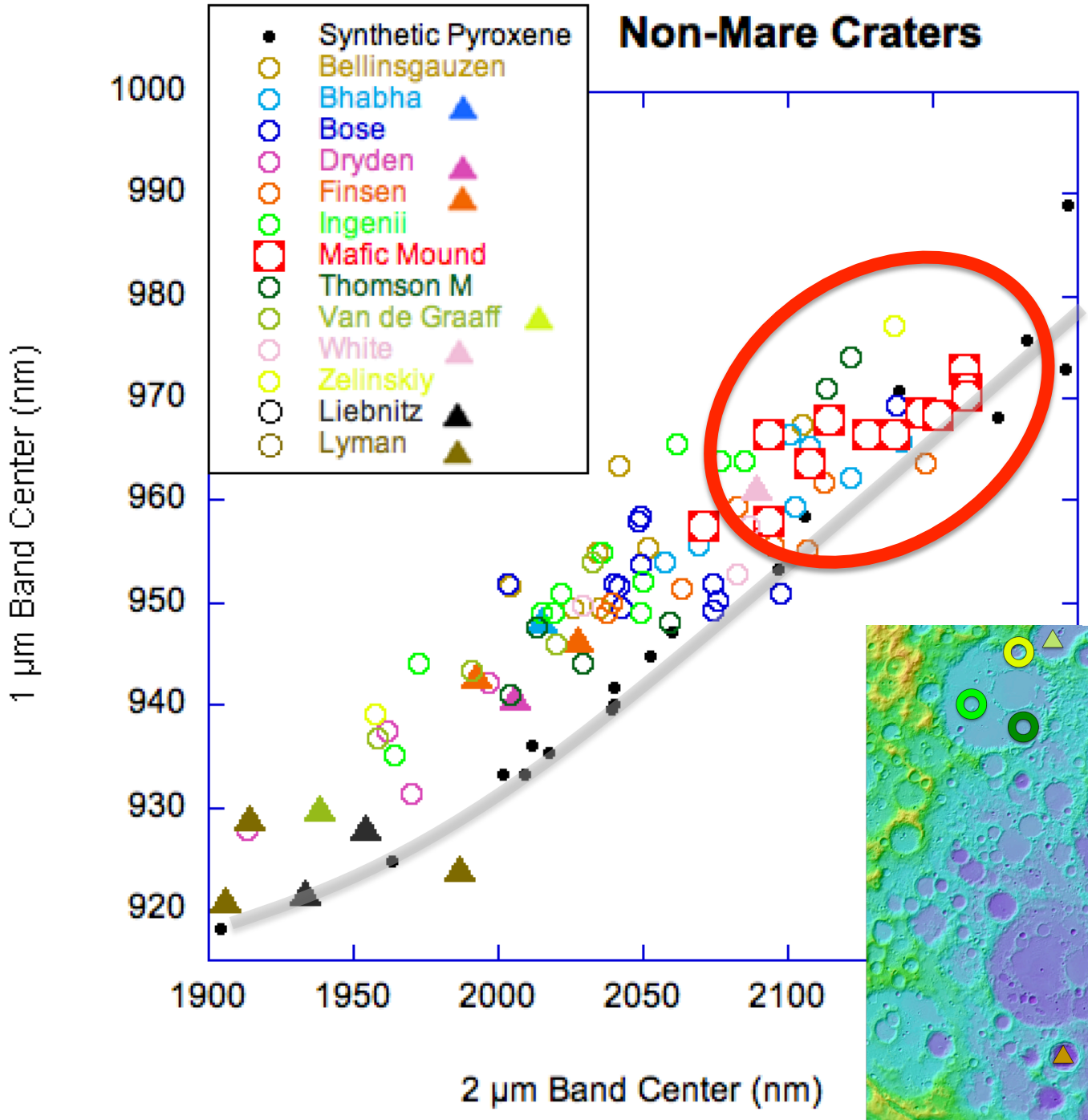


Non-mare craters in SPA exhibit a wide range of compositions.

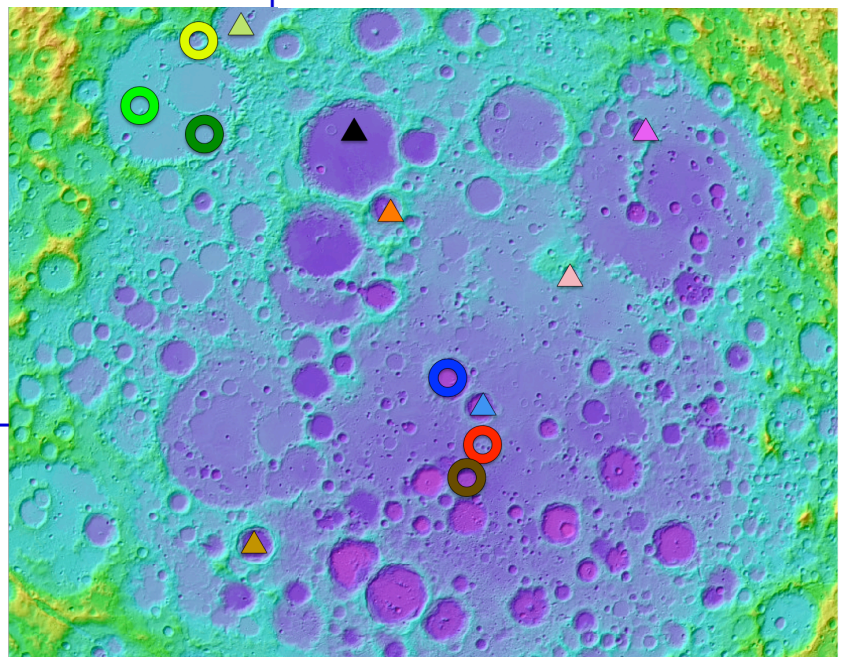


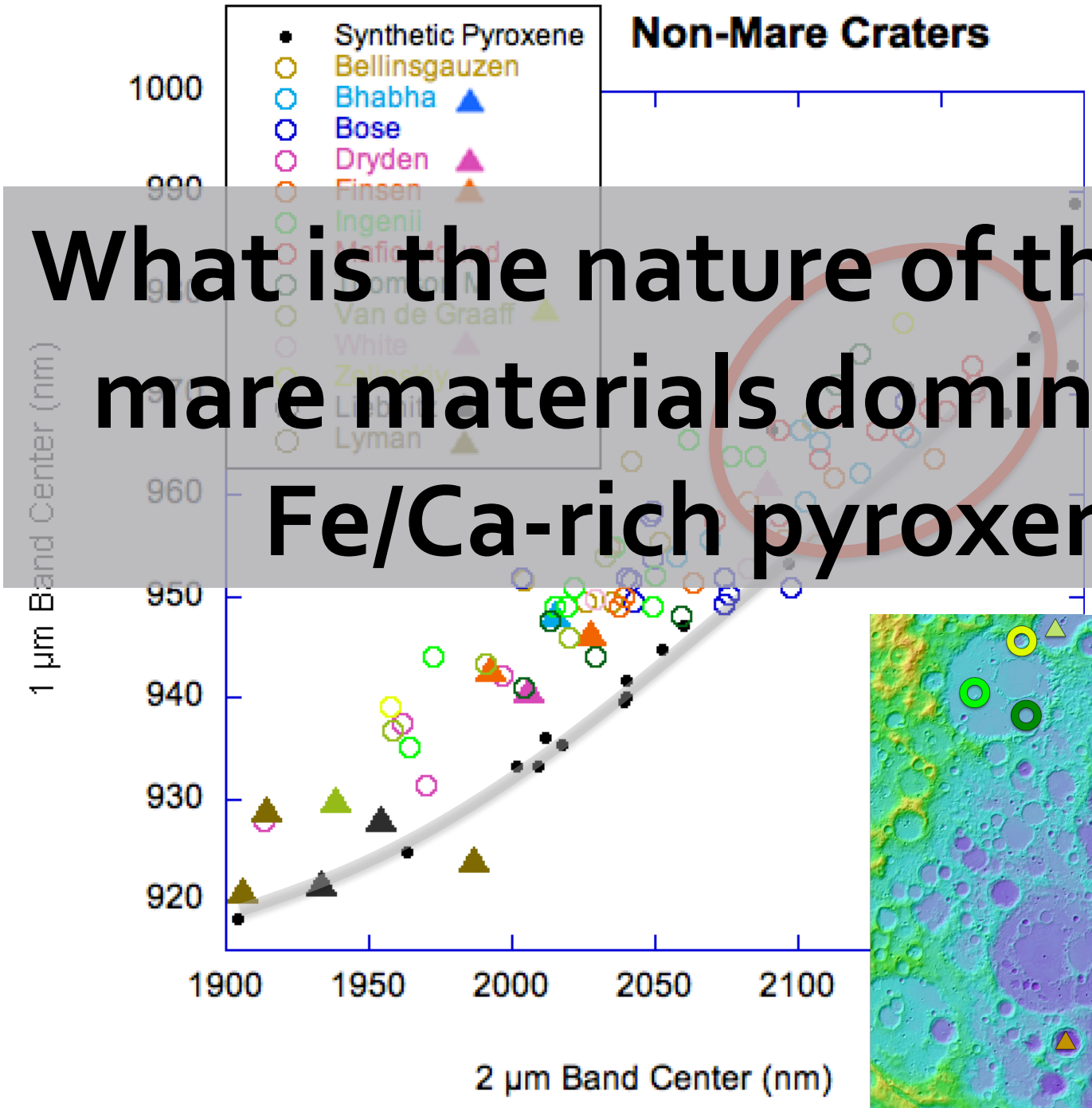
Central peaks exhibit the shortest band centers and are dominated by the most Mg-rich pyroxenes in SPA.





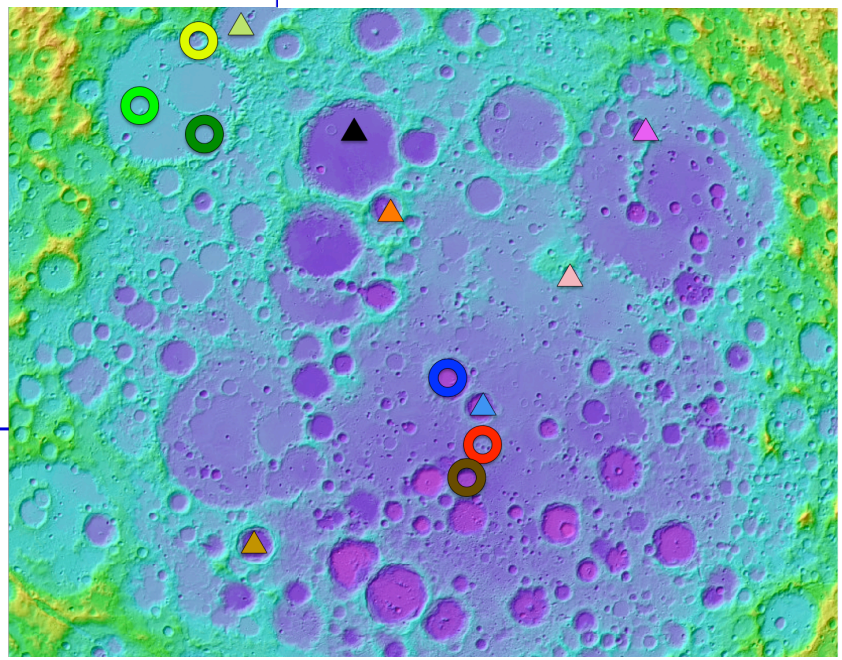
Mafic Mound and a few other exposures exhibit long-wavelength bands, indicating more Fe/Ca-rich pyroxenes.

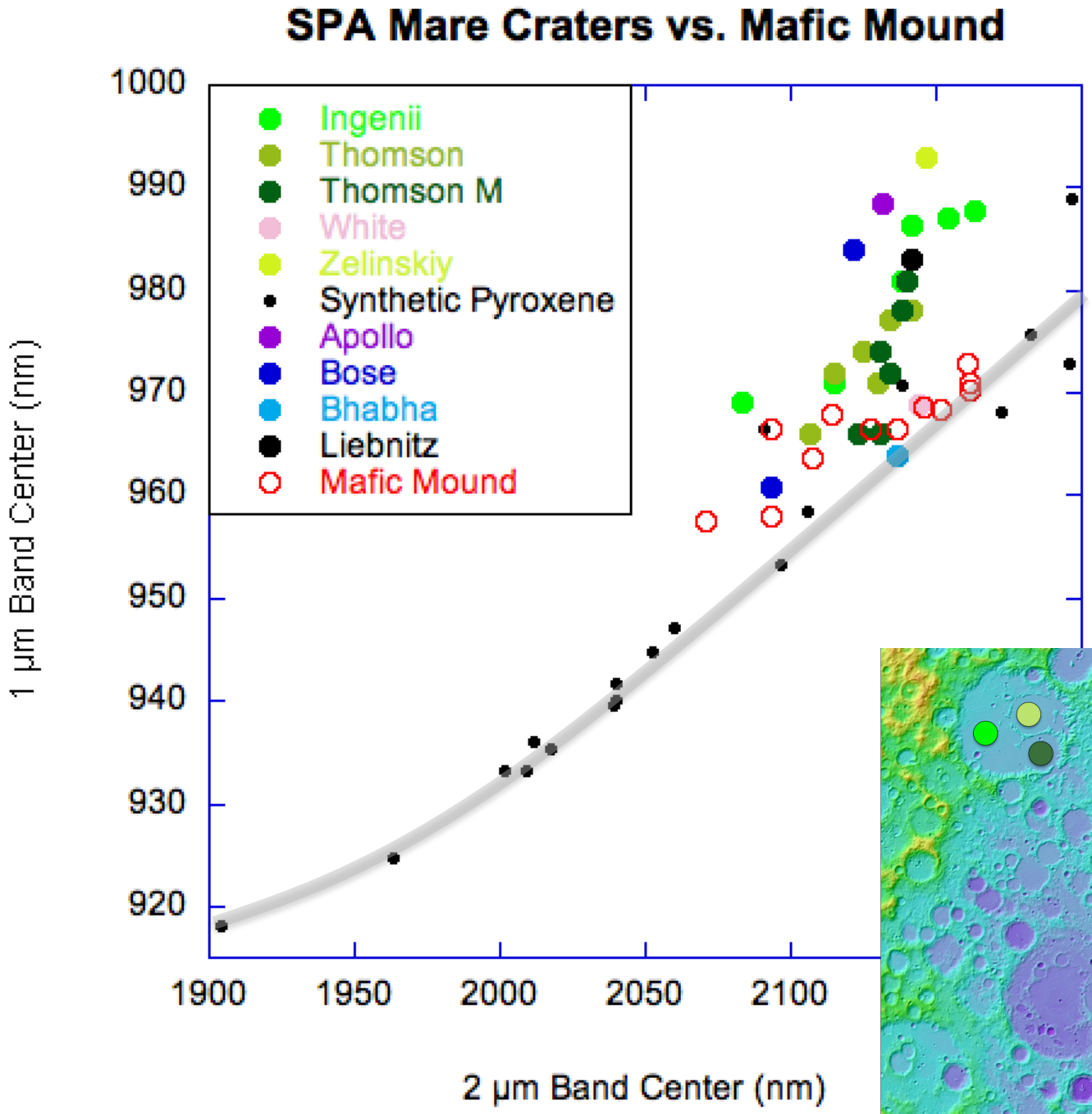




Mafic Mound and several other exposures exhibit long-wavelength bands showing more Fe/Ca.

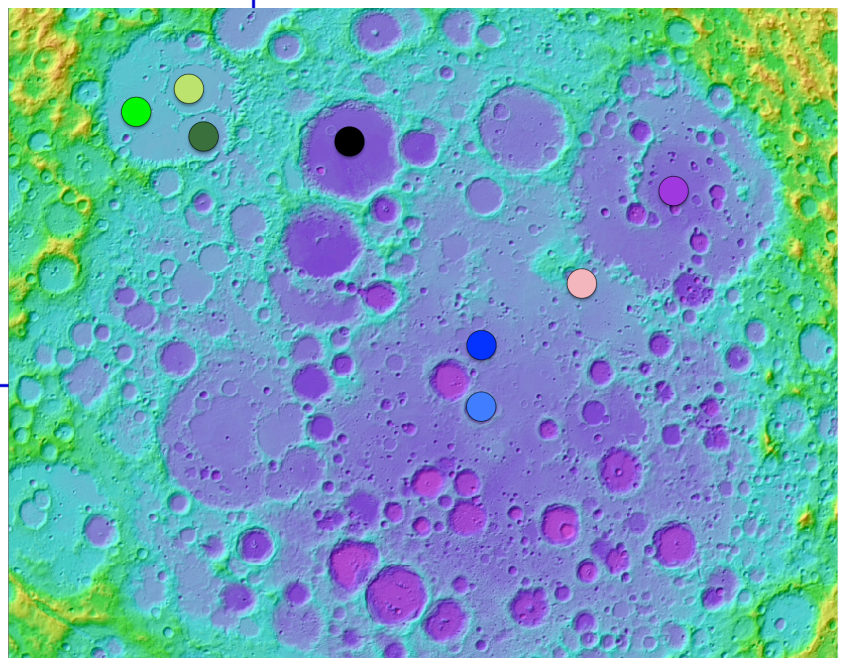
What is the nature of these non-mare materials dominated by Fe/Ca-rich pyroxenes?

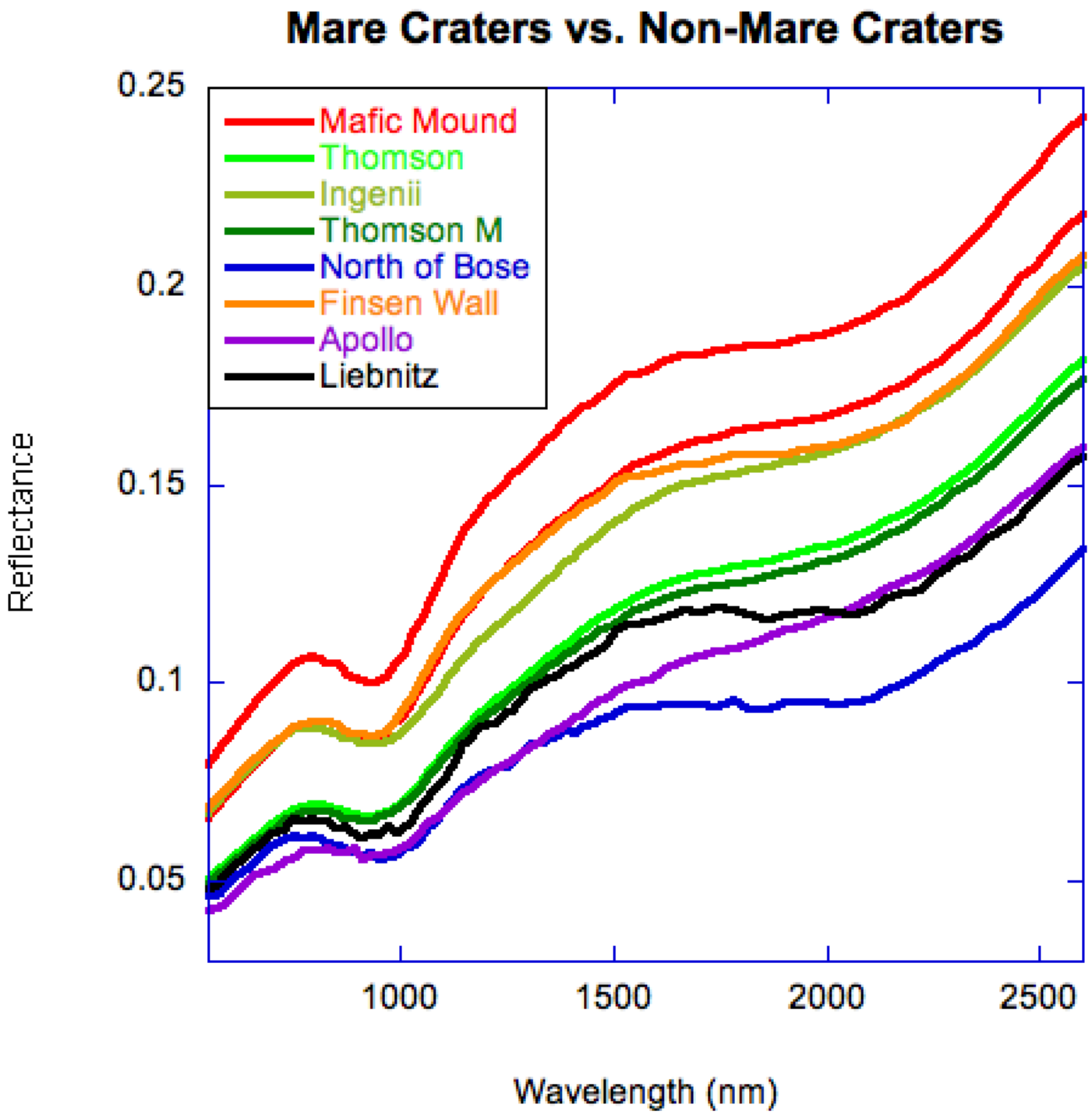




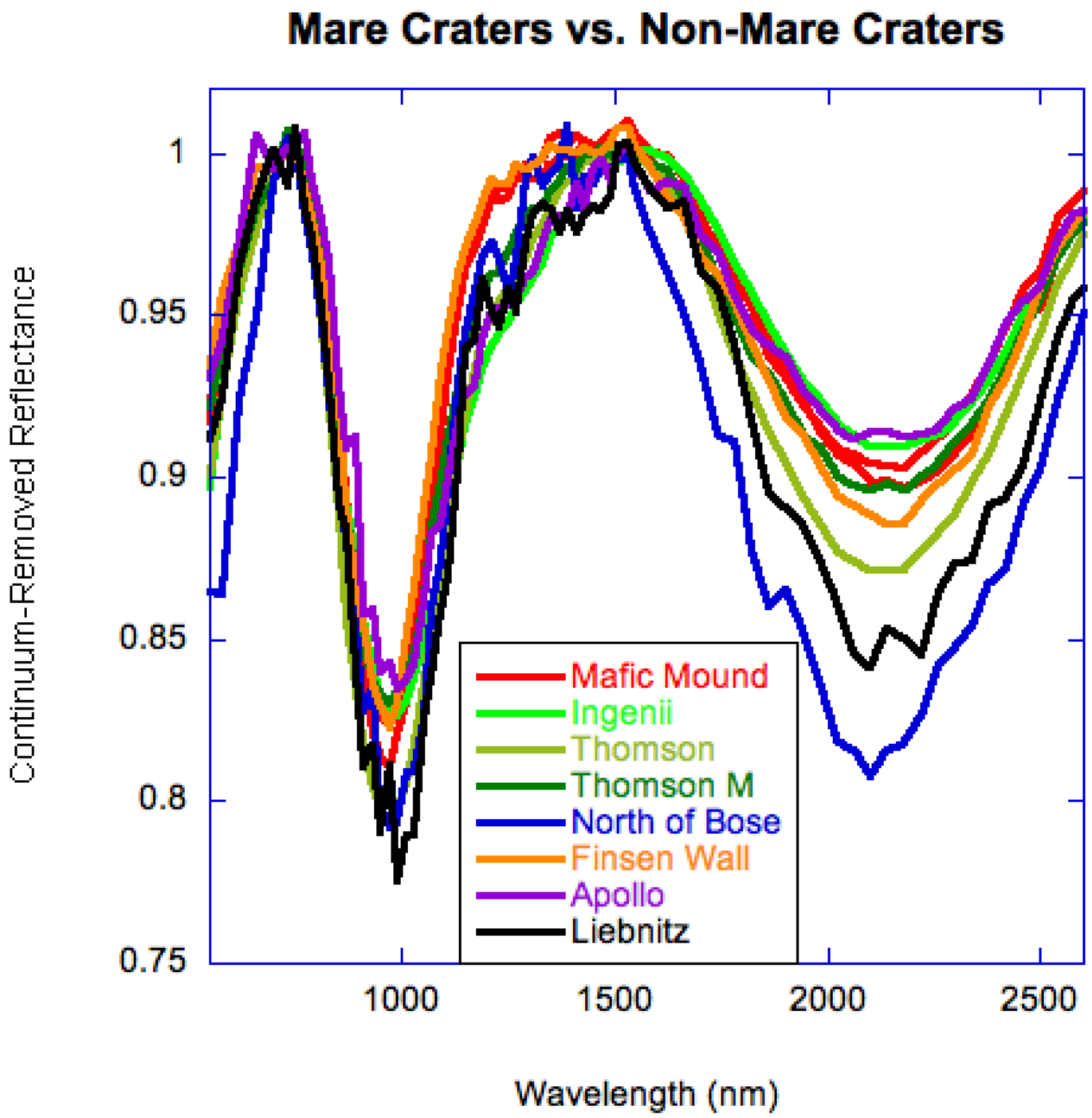
The pyroxene composition of the non-mare materials are similar to mare craters.

However, mare craters exhibit an offset from the synthetic pyroxene trend.

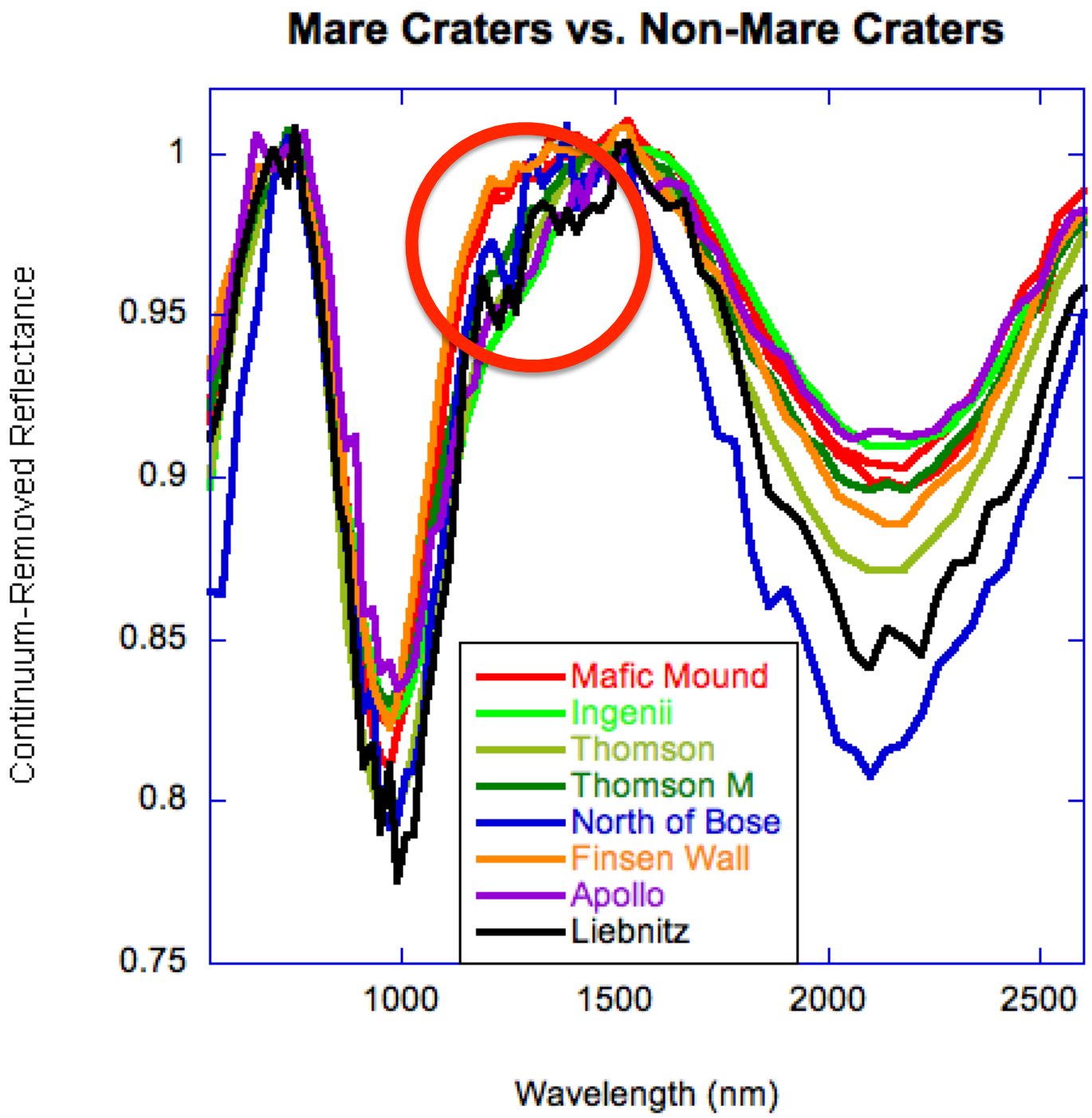




Mafic Mound and the exposure in Finsen's wall exhibit higher albedo than the mare craters.

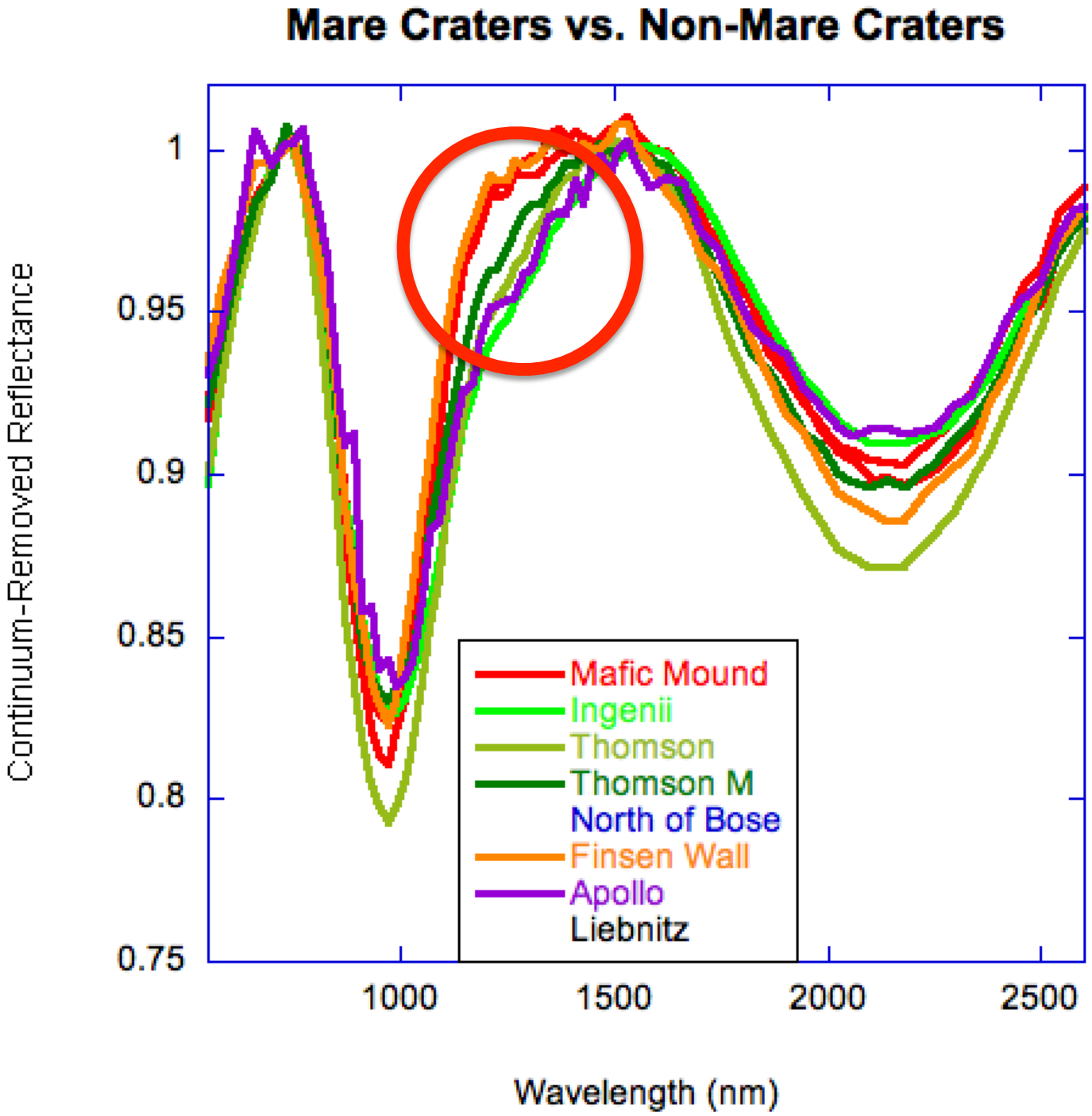


These materials exhibit similar band centers, indicating similar compositions.



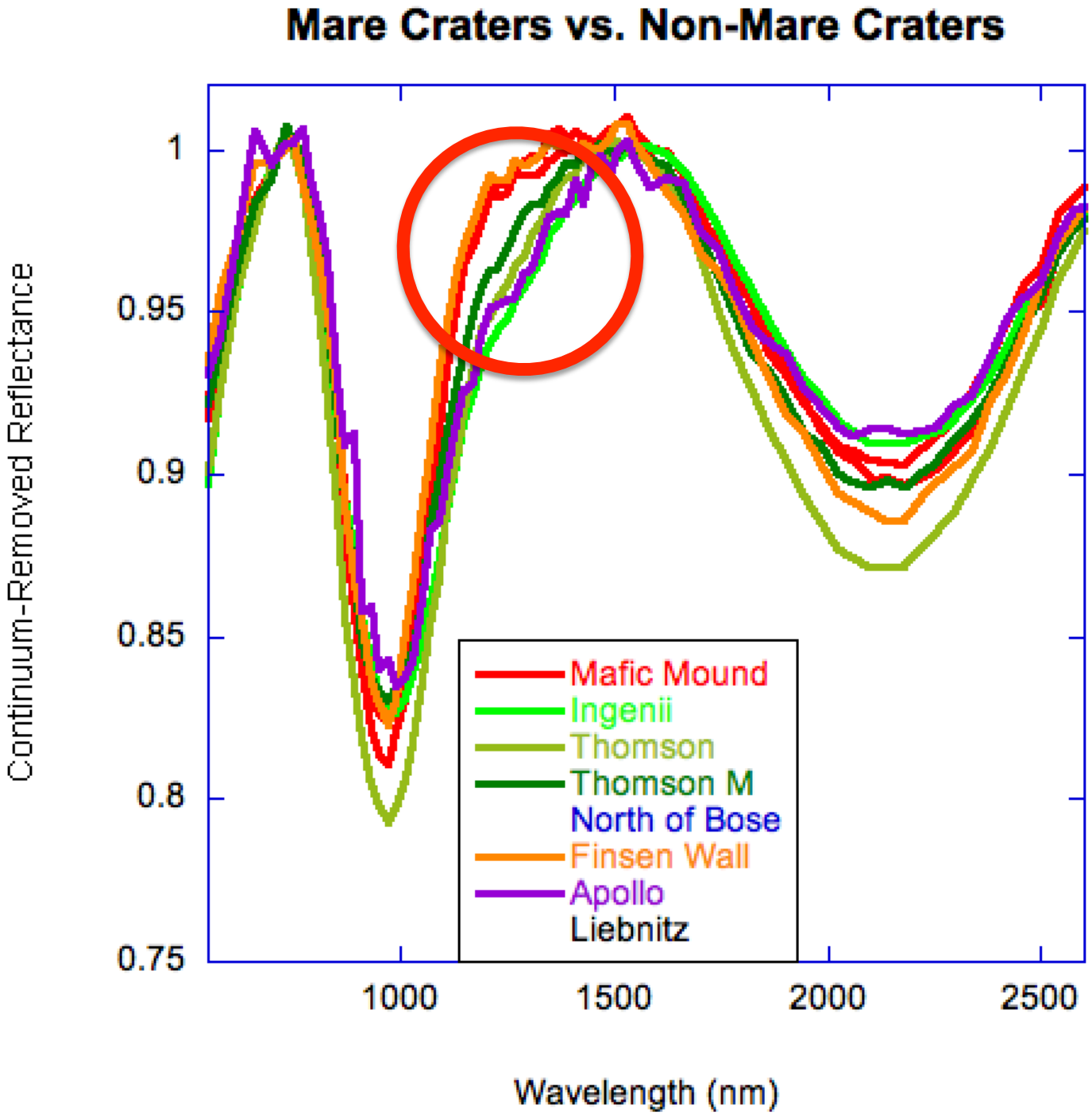
These materials exhibit similar band centers, indicating similar compositions.

Mare craters exhibit a strong 1.2 μm band; the non-mare exposures do not.



These materials exhibit similar band centers, indicating similar compositions.

Mare craters exhibit a strong 1.2 μm band; the non-mare exposures do not.

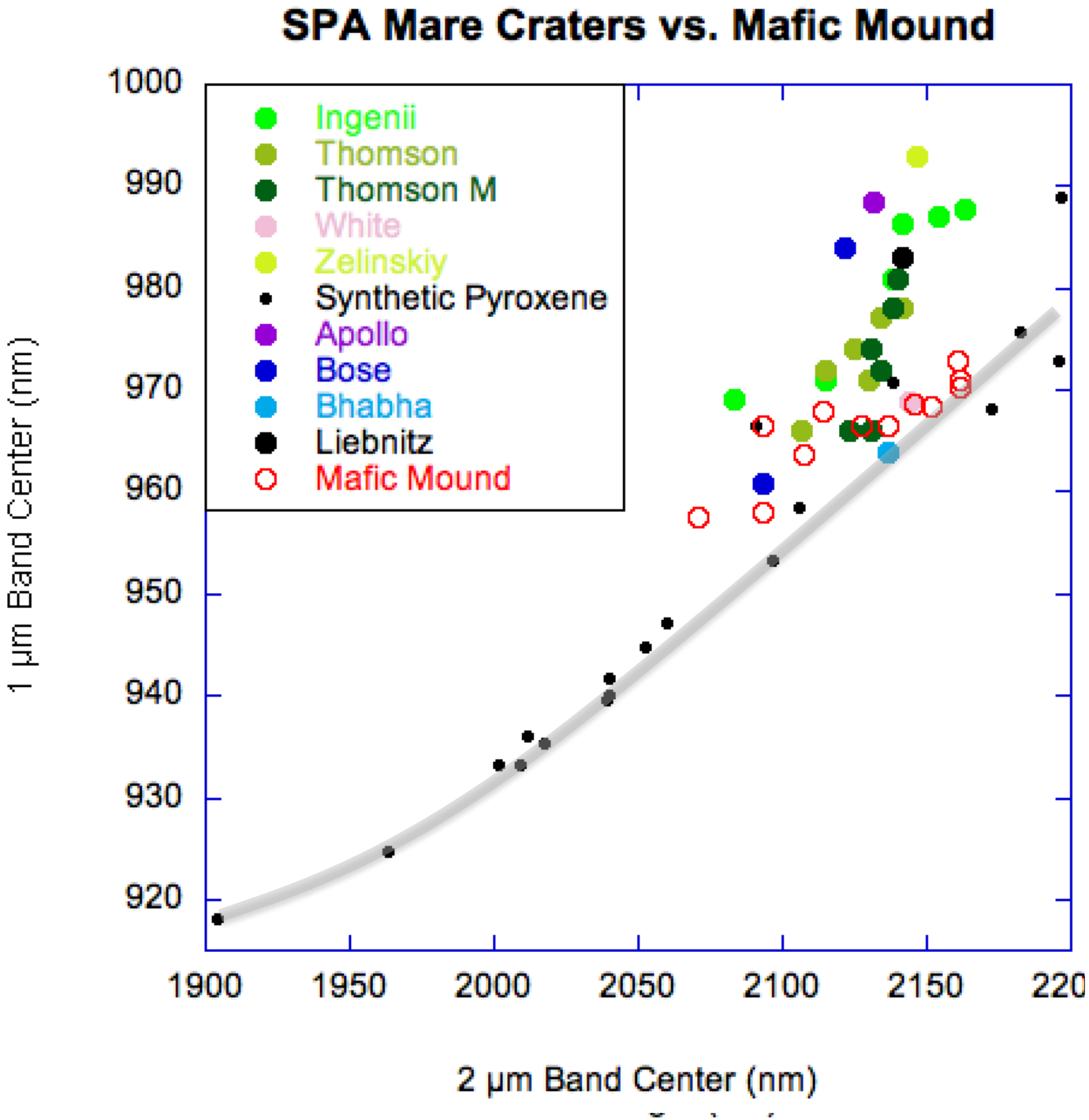


These materials exhibit similar band centers, indicating similar compositions.

Mare craters exhibit a strong 1.2 μm band; the non-mare exposures do not.

The differences in the 1.2 μm band must be due to cooling history, since the pyroxenes appear similar in composition.

These non-mare materials cooled slowly.



For mare craters, the strong 1.2 µm band contributes to the observed offset in 1 µm band center.

Conclusions

- Diverse pyroxene compositions have been identified across the SPA basin.
  - Central peaks (which sample ~10 km depth) are dominated by relatively Mg-rich pyroxenes, but exhibit a significant range in pyroxene composition.
  - Non-peak crater structures (walls, rims, floors, etc.) exhibit a wider range in pyroxene composition and are often dominated by pyroxenes richer in Fe/Ca.

Conclusions

- Mafic Mound and a few other non-mare exposures are dominated by a distinct pyroxene composition higher in Fe and Ca.
  - These exposures exhibit a similar pyroxene composition as mare basalts.
  - These pyroxenes are distinct from mare basalts in that they lack a strong 1.2 μm band, indicating slow cooling.